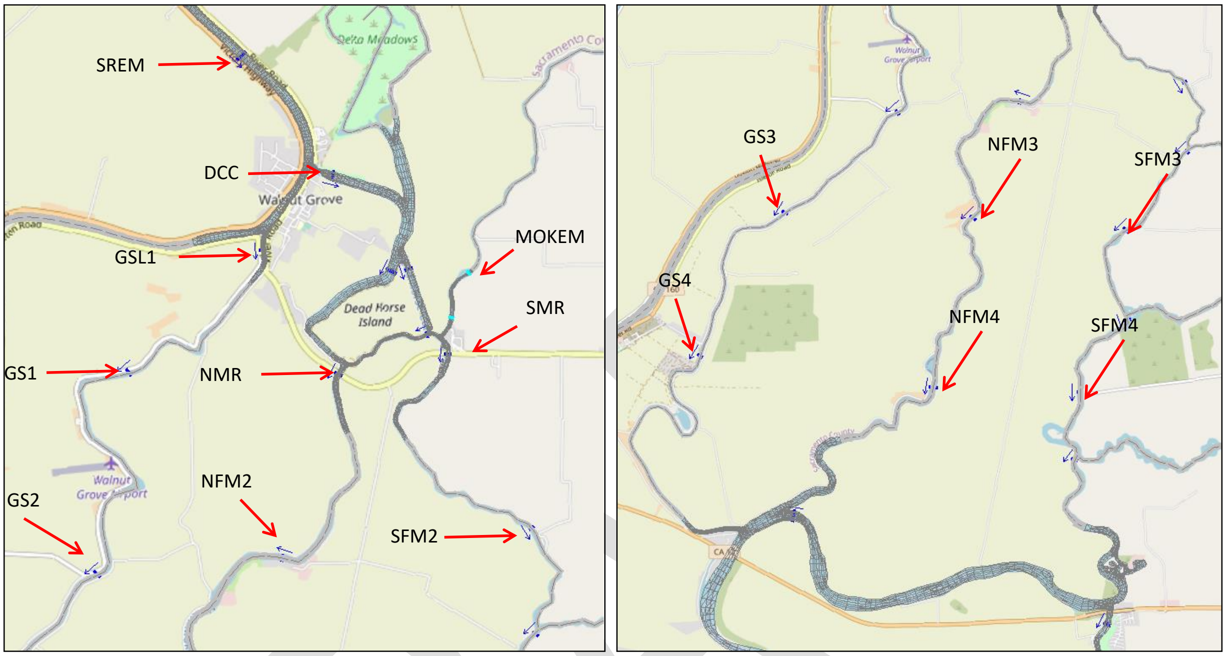
Sacramento River Nutrient Change Study



Particle Capture Locations and Nomenclature

Presented to:

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Introduction

This report includes documentation on numerical modeling tasks prepared by Resource Management Associates (RMA) for the Sacramento Regional County Sanitation District's (Regional San) Sacramento River Nutrient Change project. The development background and results from the primary tasks is included. One task specified refinement of the RMA Delta model grid for enhancing spatial resolution in the area of interest of the project as well as a check on the flow and stage calibration in this area of interest in a historical time frame. Sections 1 and 2 document the results of this work. As a preliminary step, a flow model covering the project time span was developed and its accuracy checked against measured data as documented in Section 3. In order to calculate volumetric percentages using a tracer modeling approach, a project specific transport model was developed covering the data acquisition period for the project. An EC model was developed as a template for the volumetric transport model to modify transport dispersion parameters reflecting changes to the modified grid. This is documented in Section 4. Section 5 documents the development, background and results from a particle tracking model.

Section 1 Grid Development –

A particular focus of the Sacramento River Nutrient Change study was the Mokelumne River system east of the Delta Cross Channel. The area is a complex system of interconnected channels and sloughs. River inflow is from the east from the upstream Mokelumne and Cosumnes Rivers. When the Delta Cross Channel gates are open, the flow regime is dominated by transfer flow from the Sacramento River, which varies widely in magnitude over the tidal cycle.

Specific conductance (EC) measurements performed during the field survey showed EC could vary significantly over a short distance near the channel junctions. To capture the detail of the source water mixing and attribution, the RMA Delta model grid was enhanced from 1-D elements to 2-D detailed elements in those areas (Figure 1 and Figure 2). Figure 3 shows the model bathymetry and grid detail near the Delta Cross Channel. Figure 4 the bathymetry and grid detail on the downstream North Fork and South Fork Mokelumne River.

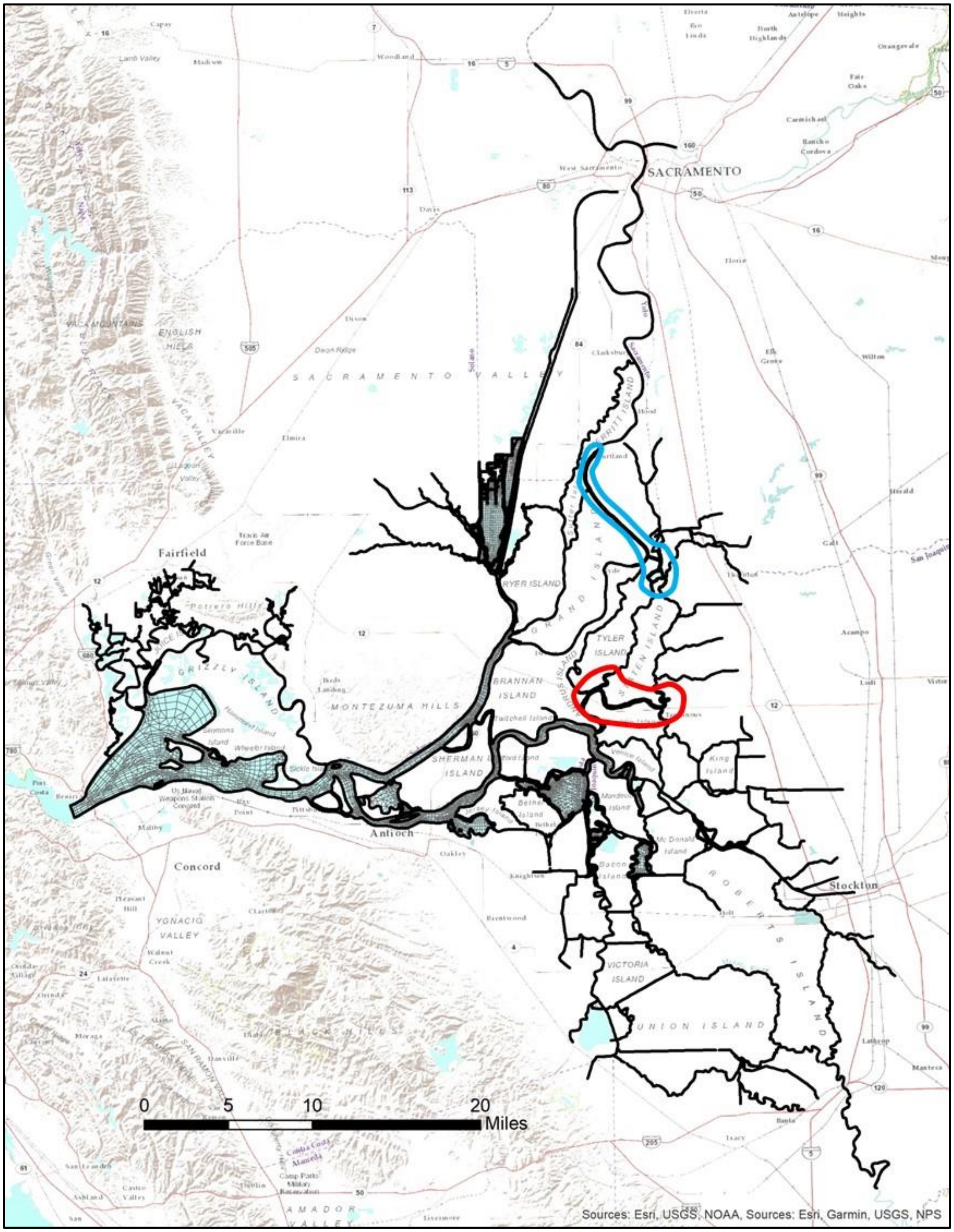


Figure 1 Coverage of the RMA Delta model, with locations of the new or refined 2-D grid development; near the Delta Cross Channel (blue) and the downstream sections of the North Fork and South Fork Mokelumne River (red).

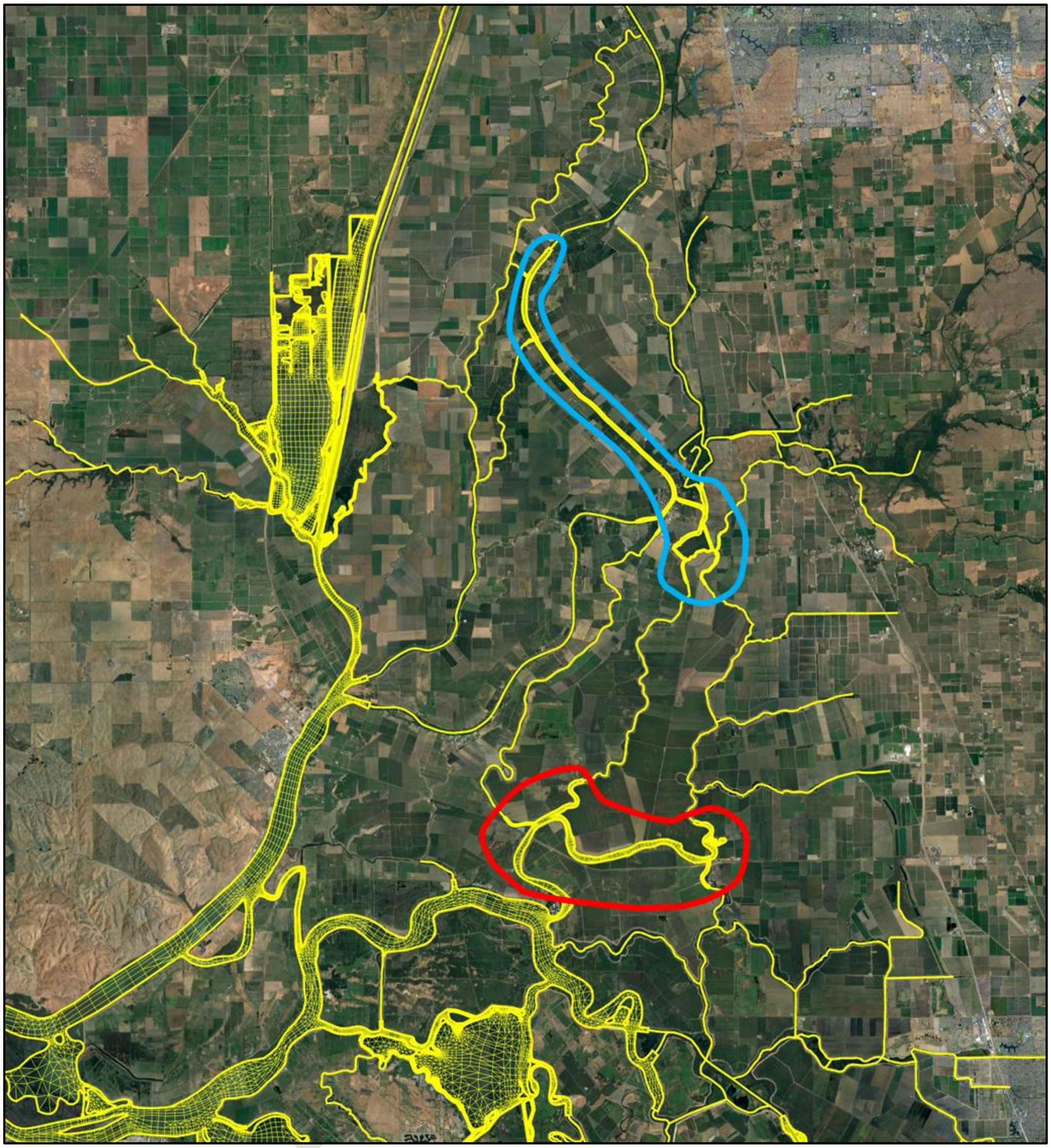


Figure 2 Additional detail for locations of new or refined 2-D grid development in the RMA model; near the Delta Cross Channel (blue) and the downstream sections of the North and South Mokelumne River (red).

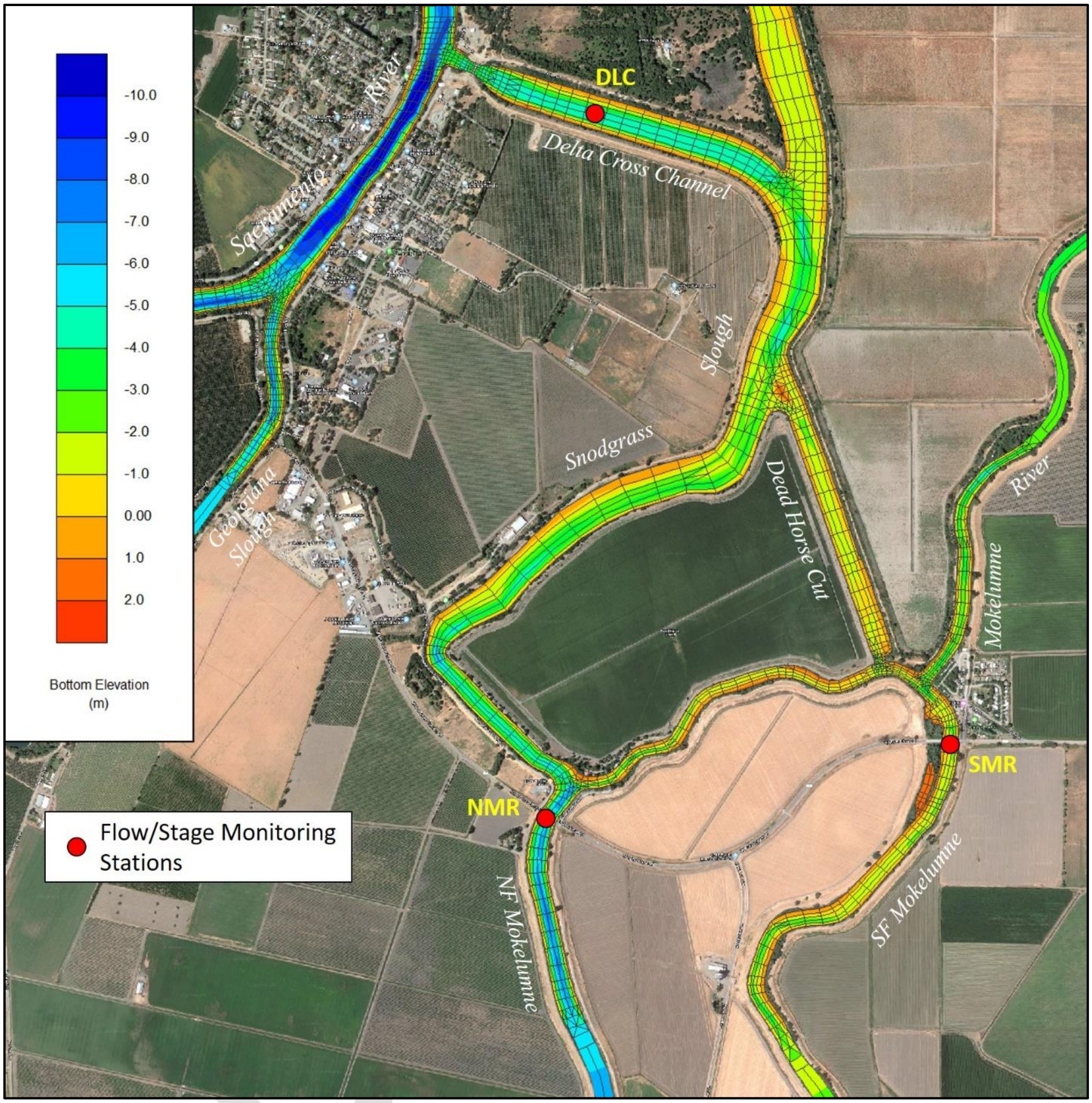


Figure 3 Detail of the model 2-D grid and bathymetry near the Delta Cross Channel.

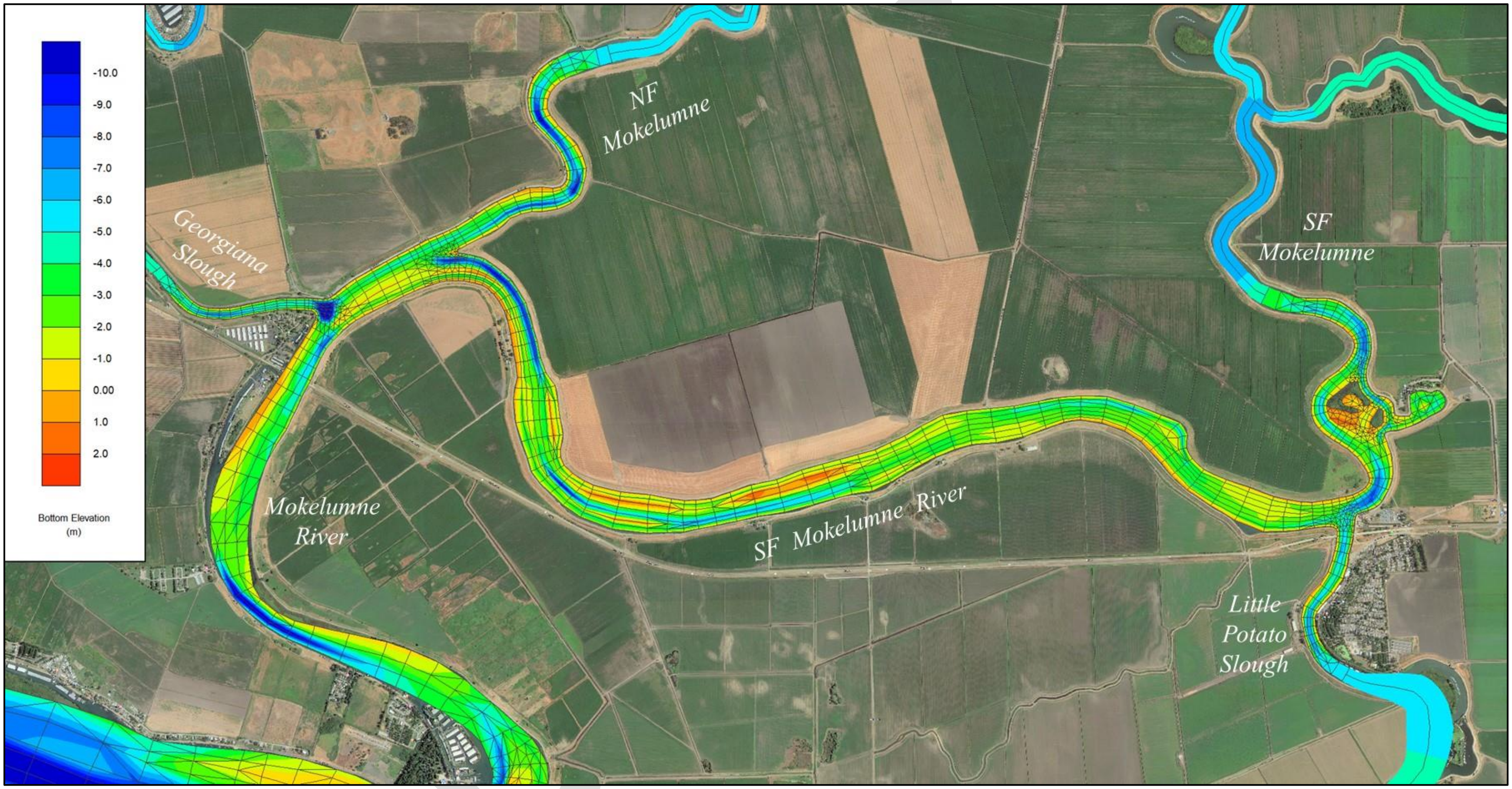


Figure 4 Detail of the model 2-D grid and bathymetry near the downstream North Fork and South Fork Mokelumne River.

Section 2 RMA-2 Calibration

The revised RMA Delta grid developed and documented in Section 1 was calibrated/validated for flow and stage in the north Delta, with special interest to the Delta Cross Channel and the north and south forks of the Mokelumne River system.

The North Fork and South Fork Mokelumne River flow monitoring stations east of the Delta Cross Channel were lost during the 2017 winter season. As these locations are of particular interest, the calibration run was performed over the June 1 to July 31, 2016 period when the flow gauges were still functioning. Figure 5 shows the flow for the Sacramento River at Freeport, and the Mokelumne and Cosumnes Rivers for the calibration period. Also presented is the Delta Cross Channel gates operation. Note that the DCC gates were open and closed twice in early June before permanently open for the summer season on June 18, 2016. In comparison to the 2019 field season, the 2016 June-July Sacramento River flow was somewhat lower, but higher than that for the previous three years of drought. The Mokelumne River flow was about 200 cfs in June 2016, similar to the flow in the first half of September 2019 during the field study. However, the early 2019 summertime Mokelumne River flow was much higher at 680 to 1500 cfs.

The observed and model stage/flow at selected Delta monitoring stations are compared in 3-panel plots as illustrated in Figure 7.

- The top panel provides a visual comparison of the 15-minute interval observed and computed stage/flow to illustrate how well the model reproduces the inter-tidal dynamics of the system.
- The lower-left panel provides a visual comparison of the tidally-averaged (two passes of 24.75 hour moving average window) observed and computed stage/flow time series to illustrate how well the model reproduces the net flow or average stage over the simulation period.
- The lower-right panel presents a linear regression analysis of 15-minute computed and model stage or flow to provide statistical values of the model performance.
-

Calibration Statistics

Mean value and linear regression statistics were computed from 15-minute interval values of the model and observed time series over the June 1 to July 31 period (Figure 7) and provide an overall measure of the model bias. Model values were excluded from the mean value computation for the times when observed values were missing.

A cross-correlation analysis was first performed to determine the phase lag between the model and observed data time series. The phase difference was removed from the model time series and a linear regression perform for the shifted model time series versus the observed data time series. The regression metrics are described below.

Lag – The time offset for which the best correlation between model and observed data is obtained. Positive time lags indicate delayed model response relative to observed data. Negative time lags indicate model response in advance of observed data.

Tidal Amp Ratio – The slope of the best linear regression line between the tidal components of the modeled and observed data. This is calculated after the tidally-averaged signal has been removed from both data sets and the model data has been shifted to account for any time lag from the observed data. Amplitude ratios greater than 1.0 indicate an amplification of the tidal signal in the model relative to observed data. Amplitude ratios less than 1.0 indicate a dampening of the tidal signal.

R^2 – The square of the correlation coefficient for a linear regression between modeled and observed data. The better the model is at reproducing detailed variations and trends of the observed values, the smaller the scatter will be and the closer R^2 will be to 1. Additionally, the slope of the regression line should be close to 1 to indicate a good fit.

Calibration plots of stage and flow for the Delta Cross Channel and the north and south fork Mokelumne River stations (Figure 6) are presented in Figure 7 to Figure 10. The figures show the model reproduces the observed stage and flow in the area for both the case with the DCC gates open and closed. Of note are the intricate peaks and troughs of the South Fork Mokelumne (SMF) inter-tidal flow, of which the model reproduces fairly well. All three flow station plots show the model phase is in advance of the observed flow phase. This is partly due to the observed flow being averaged over a 15-minute period which should contribute to a 7.5 minute phase lag in the observed data. Still the modeled phase remains several minutes advanced of the field measured flow and should be considered when comparing field and model water quality data.

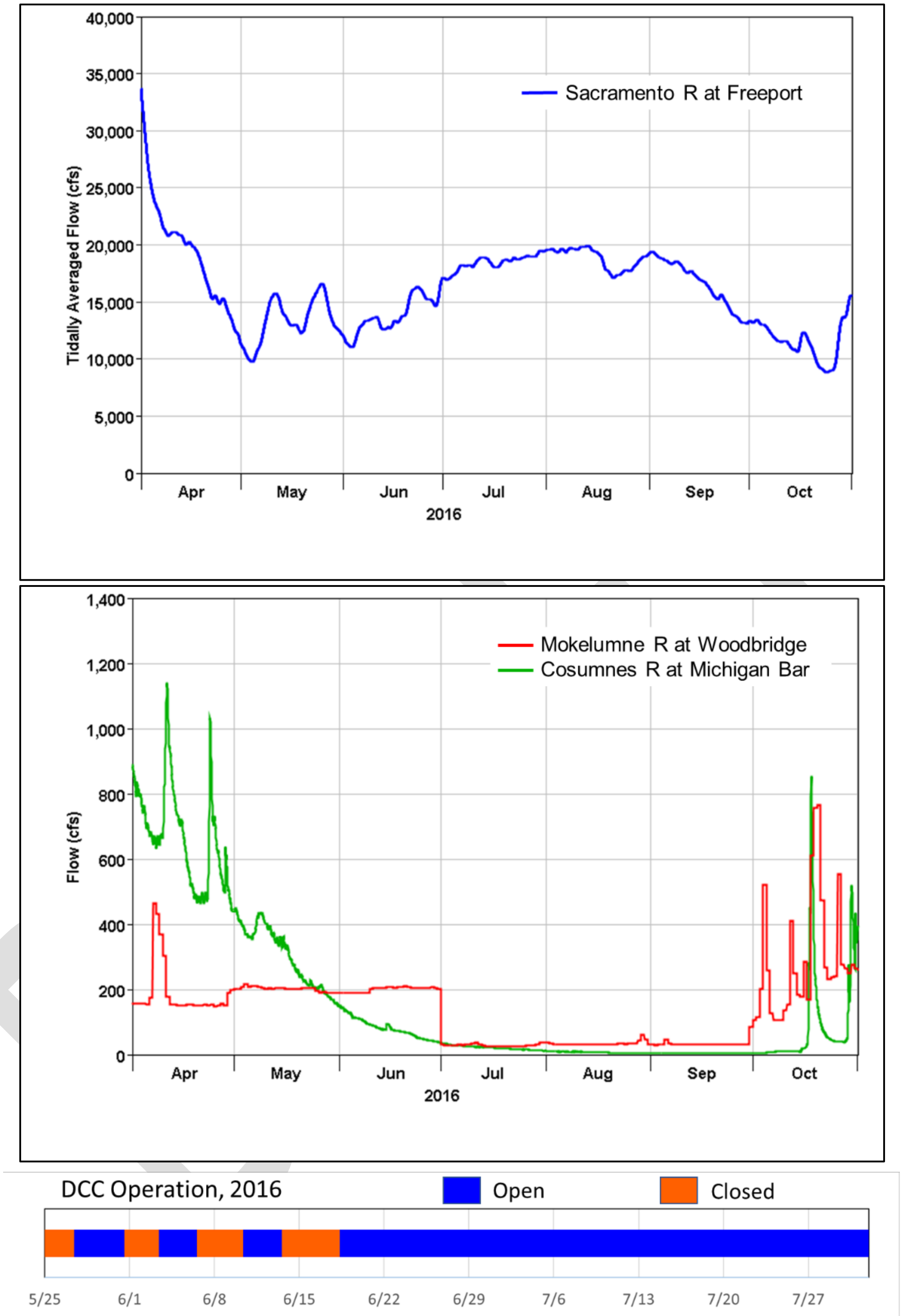


Figure 5 Inflow for the Sacramento River (top) and the Mokelumne River and the Cosumnes River (middle) for 2016 calibration. Delta Cross Channel Gate operation for 2016 calibration period (bottom).

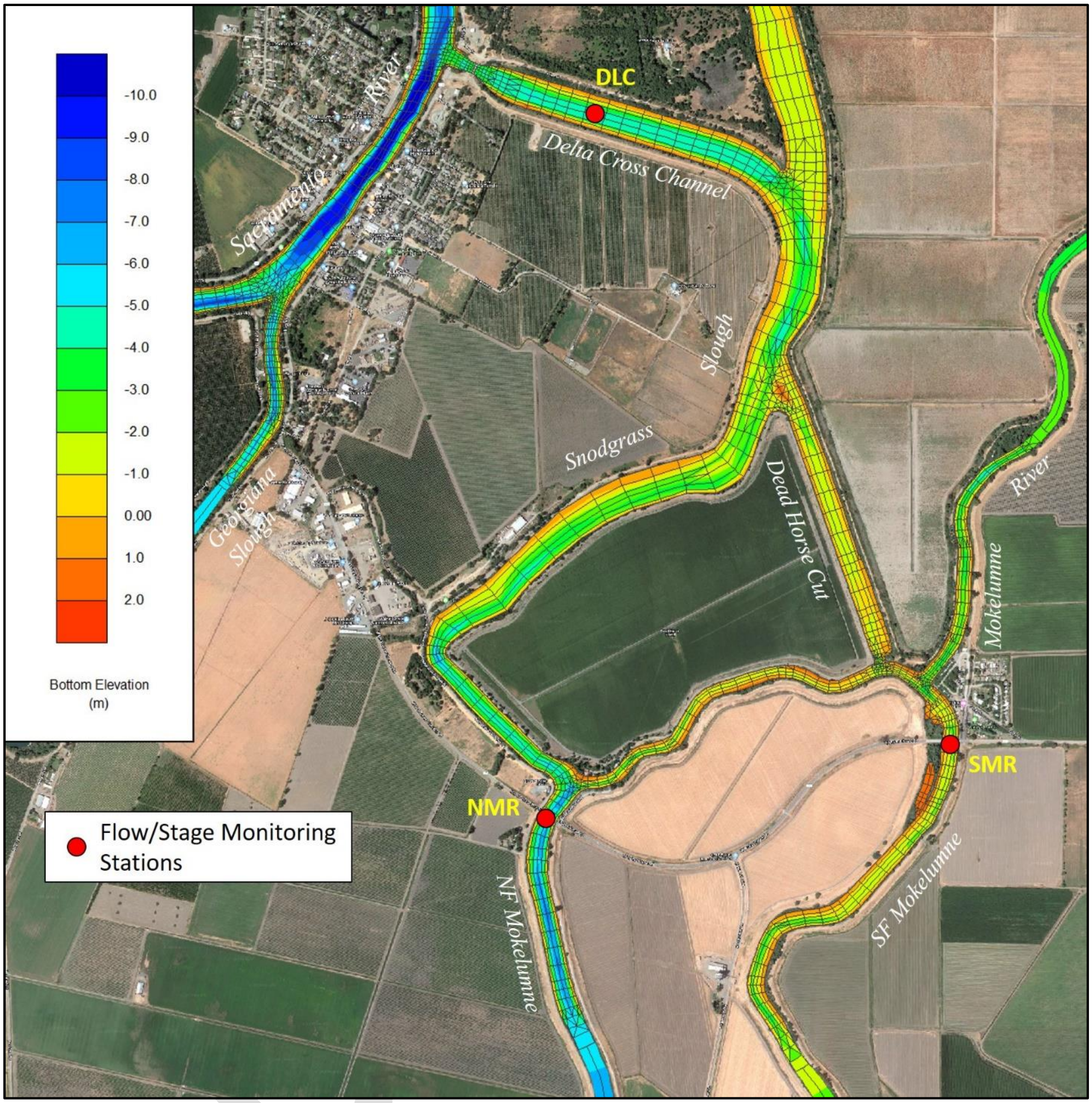


Figure 6 Detail of the model 2-D grid and bathymetry near the Delta Cross Channel.

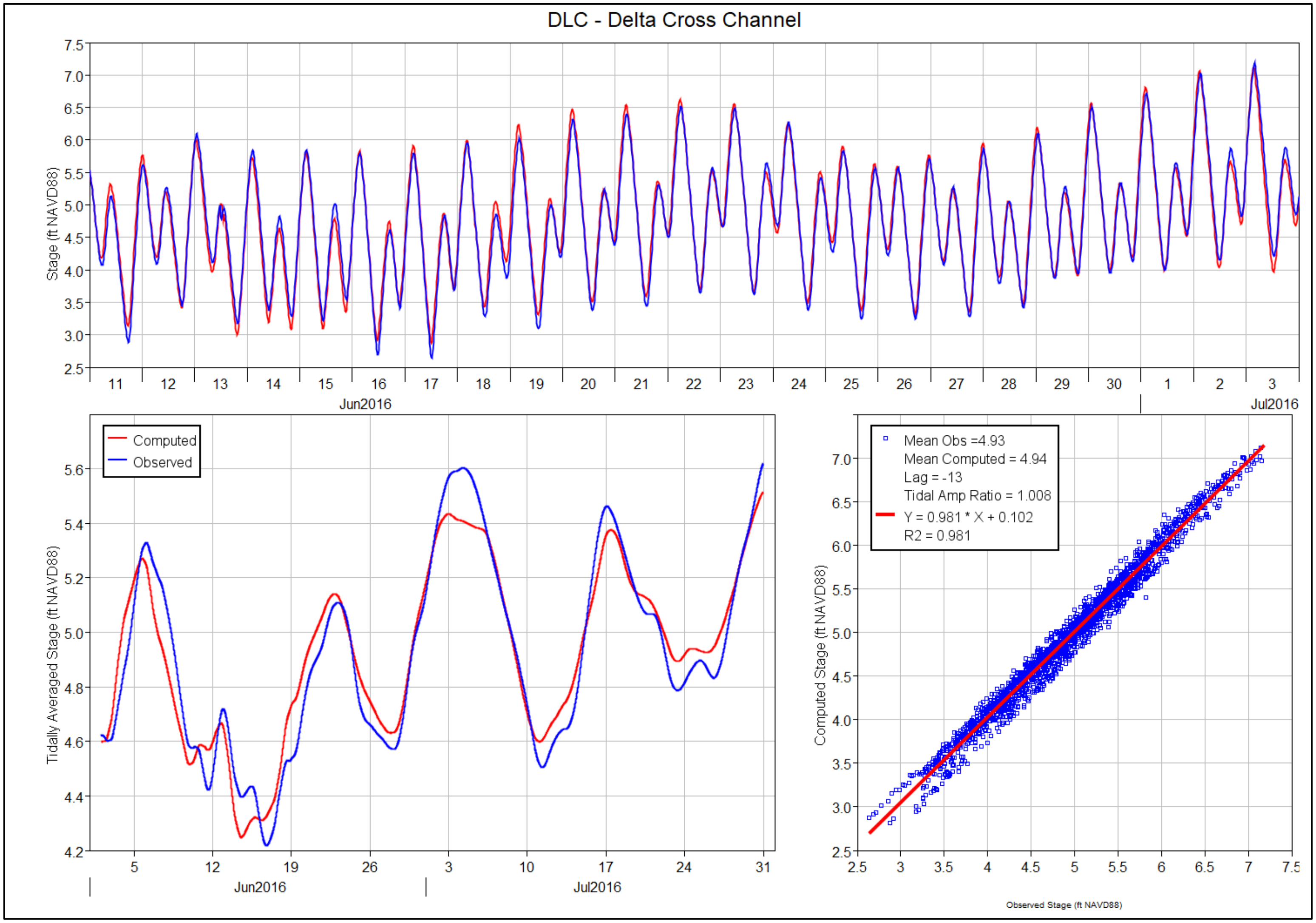


Figure 7 Model and observed stage at the Delta Cross Channel station DLC.

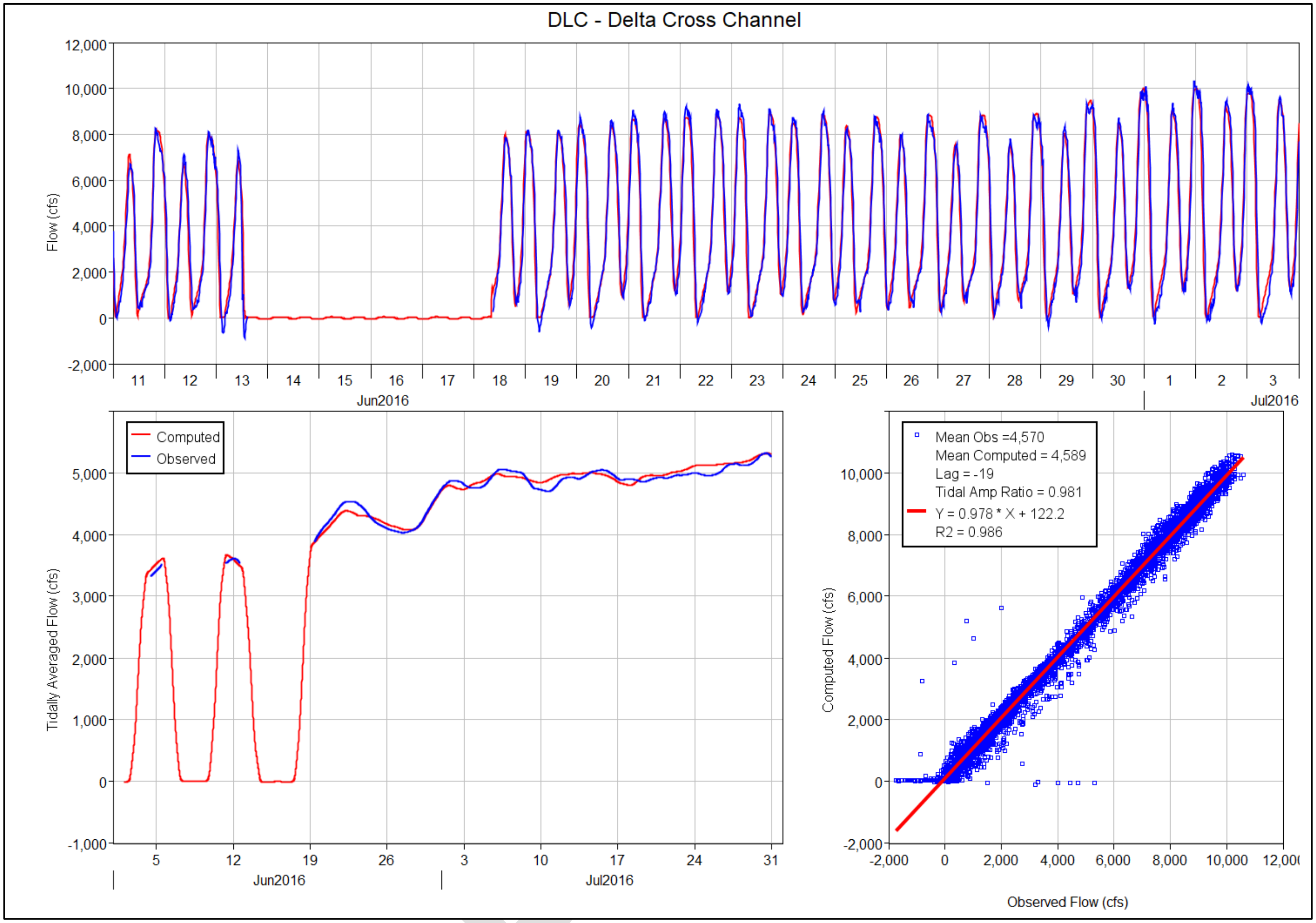


Figure 8 Model and observed flow at the Delta Cross Channel station DLC.

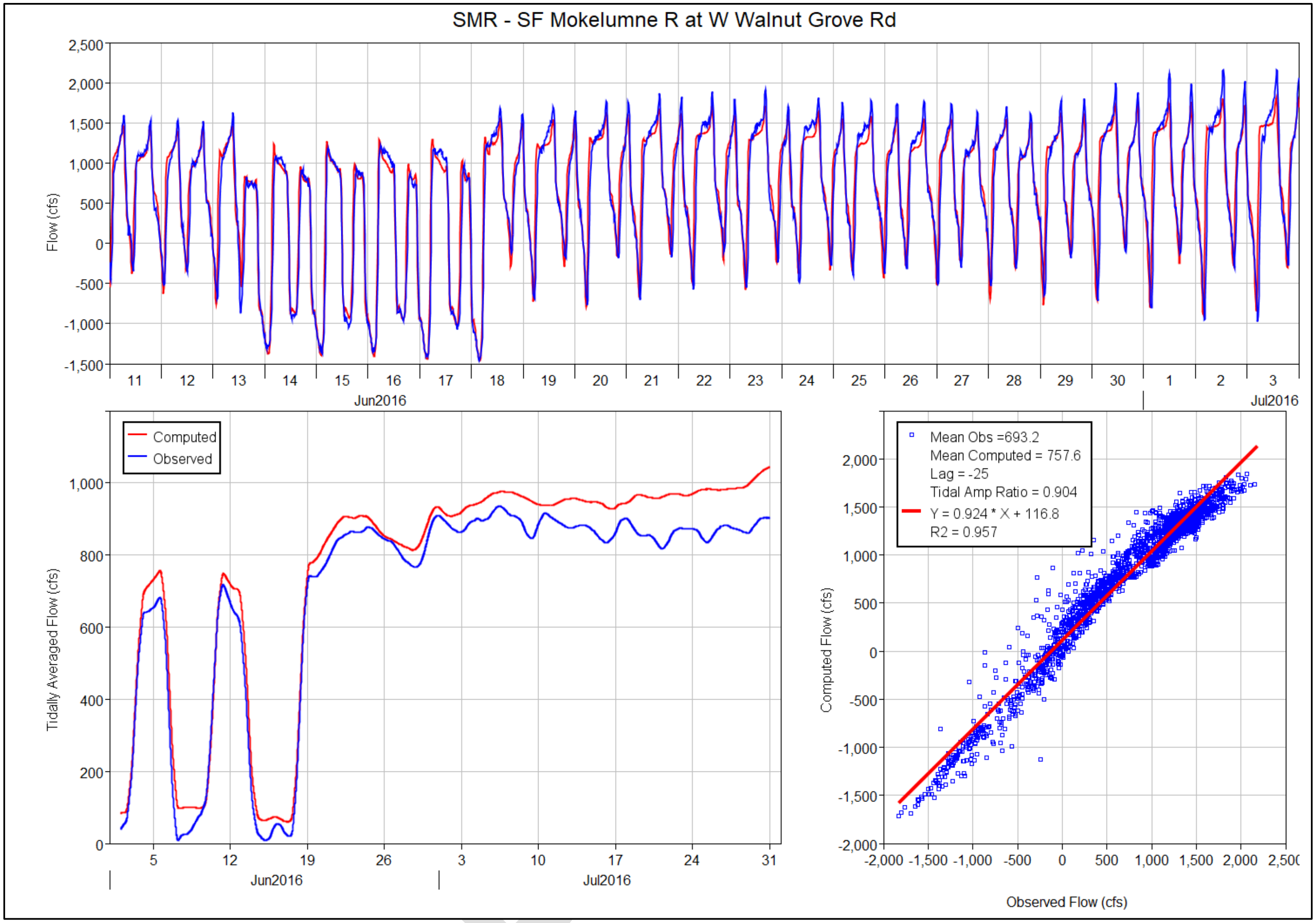


Figure 9 Model and observed flow at the South Fork Mokelumne River station SMF.

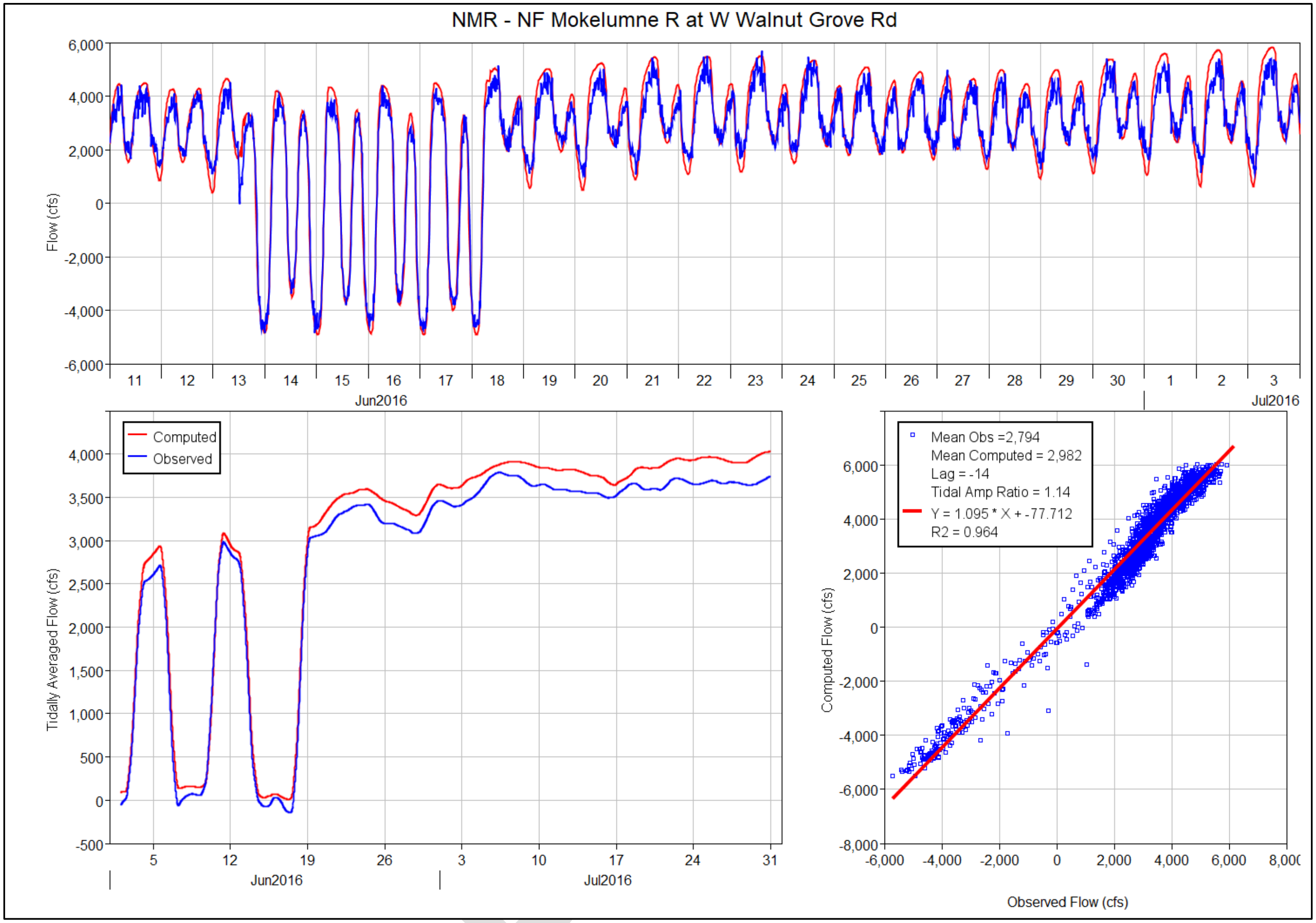


Figure 10 Model and observed flow at the North Fork Mokelumne River station NMF.

Section 3 Development of Flow/Stage Modeling for the Project

Starting from the calibrated RMA2 model with the updated grid developed for this project (see: Sections 1 and 2), project-specific inflow boundary conditions and comparison data were obtained for the relevant time span from standard data sources (CDEC, USGS, NOAA) as well as flow data for the Mokelumne River sourced from personal communications with staff at the East Bay Municipal Utility District, EBMUD. Regional San effluent flow and EC data was obtained from Regional San staff (Timothy Mussen). Figure captions indicate the data source for each relevant boundary condition.

Figure 11 shows the RMA Delta Model domain with inflow and outflow boundary locations in pink (circles) and cyan blue (bars), DICU (Delta Island Consumptive Use) locations in yellow and gates and barriers in red. As indicated in Figure 3 and Figure 4, the focus of modeling concerned the section of the Sacramento River through Georgiana Slough and the eastern section of the Delta focusing on the DCC and the Mokelumne River. Inflow locations for the Sacramento, American, Cosumnes and Mokelumne Rivers are indicated in Figure 12 – these rivers plus the effluent flow from Regional San form the most relevant inflow locations for this project. Boundary condition data for other locations was collected from standard RMA sources (CDEC and USGS for flow, NOAA for Martinez stage).

The RMA2 flow model was prepared for the period July 4, 2019 through September 19, 2019. Simulated flow and stage output was compared with data, and minor modifications made to correct timing or level of flow. After a modification to Cosumnes River inflow described in Section 4, the final flow simulation was used for all RMA11 transport simulations as well as particle tracking simulations. Note that DICU boundary conditions (inflows and outflows) were NOT included as these values are not available in real-time. Instead, they are calculated post-fact by staff at the Department of Water Resources' Delta Modeling Section using in-house modeling software. To compensate for this missing data, the Sacramento River inflow was set so as to obtain acceptable fits to flow and net flow and stage measurements at RSAC155 (Freeport) and at a few other standard measurement locations downstream on the Sacramento River. As mentioned below, Regional San effluent flow and EC measurements were only available on a sparse, irregular data set which necessitated some fine-tuning of these flow and EC boundary conditions as modeling progressed.

Figure 13 through Figure 16 show the inflow boundary conditions for these important locations. The Freeport location, Figure 13, had relevant data at downstream locations for development of the boundary condition available for comparison. The inflow location for Regional San effluent is near (downstream) the Freeport location in the model domain. As discussed in the next section on Volumetric modeling, the Cosumnes River boundary condition was altered by adding 50 cfs to the data. The timing and magnitude of the Regional San effluent flow was fine-tuned during periods without data measurements to improve results during the calibration of the dispersion coefficients of the RMA11 model. Figure 17 and Figure 18 show the comparison between data (blue lines) and model output (red lines) at the Delta Cross Channel and Georgiana Slough locations, respectively.

The DCC was most important location with data to compare to modeled flow as this location captured Sacramento River inflow to the project region as there was no data internal to the project region for comparison. The mean percent difference between modeled tidally-averaged flow and data in the DCC was -3.2% with a standard deviation of 1.4 cfs, using 2824 data points from July 04 through August 20, 2019 (data not shown). This was deemed an acceptable difference for project purposes.

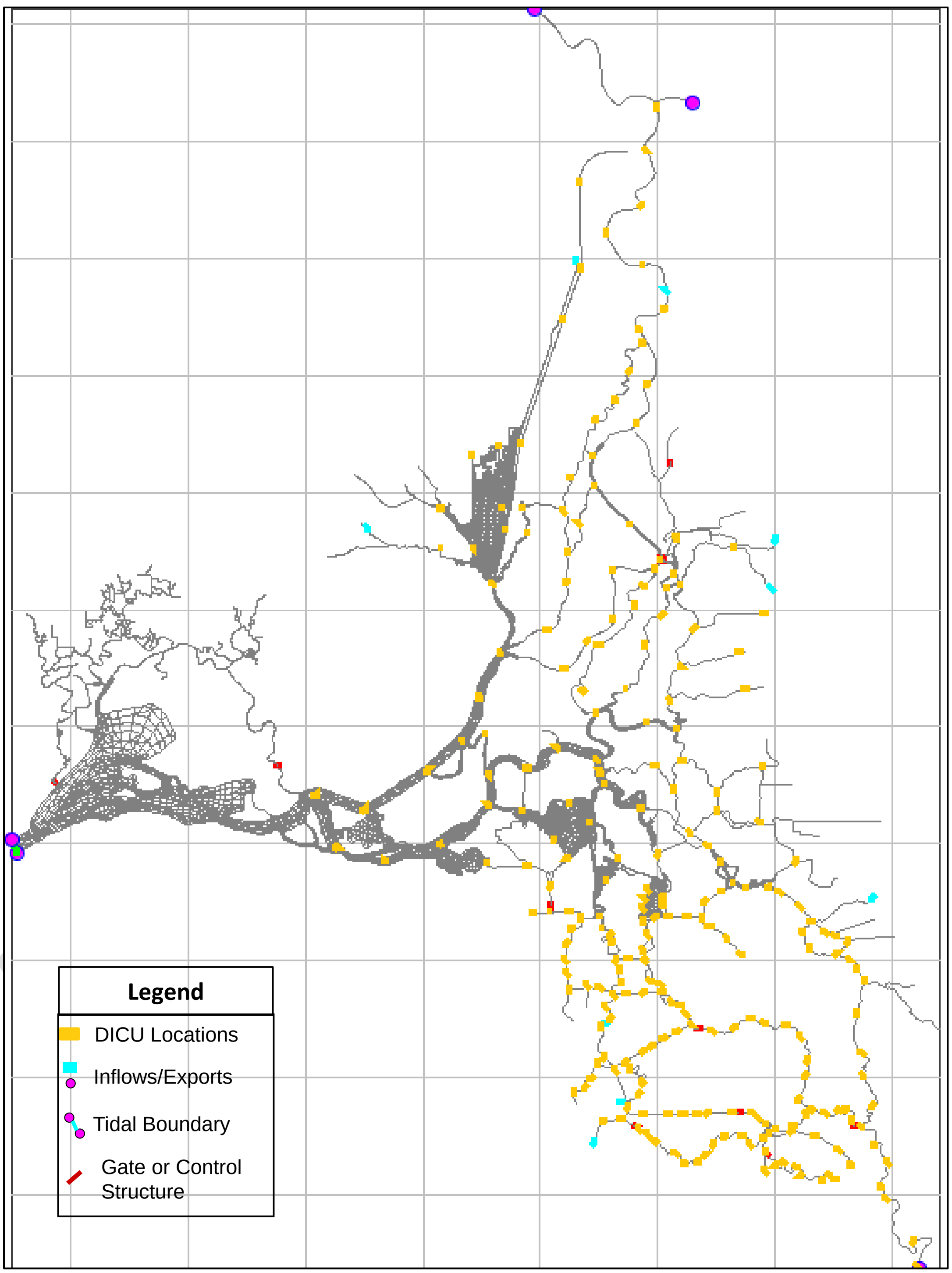


Figure 11 Model domain for the RMA Delta Model.

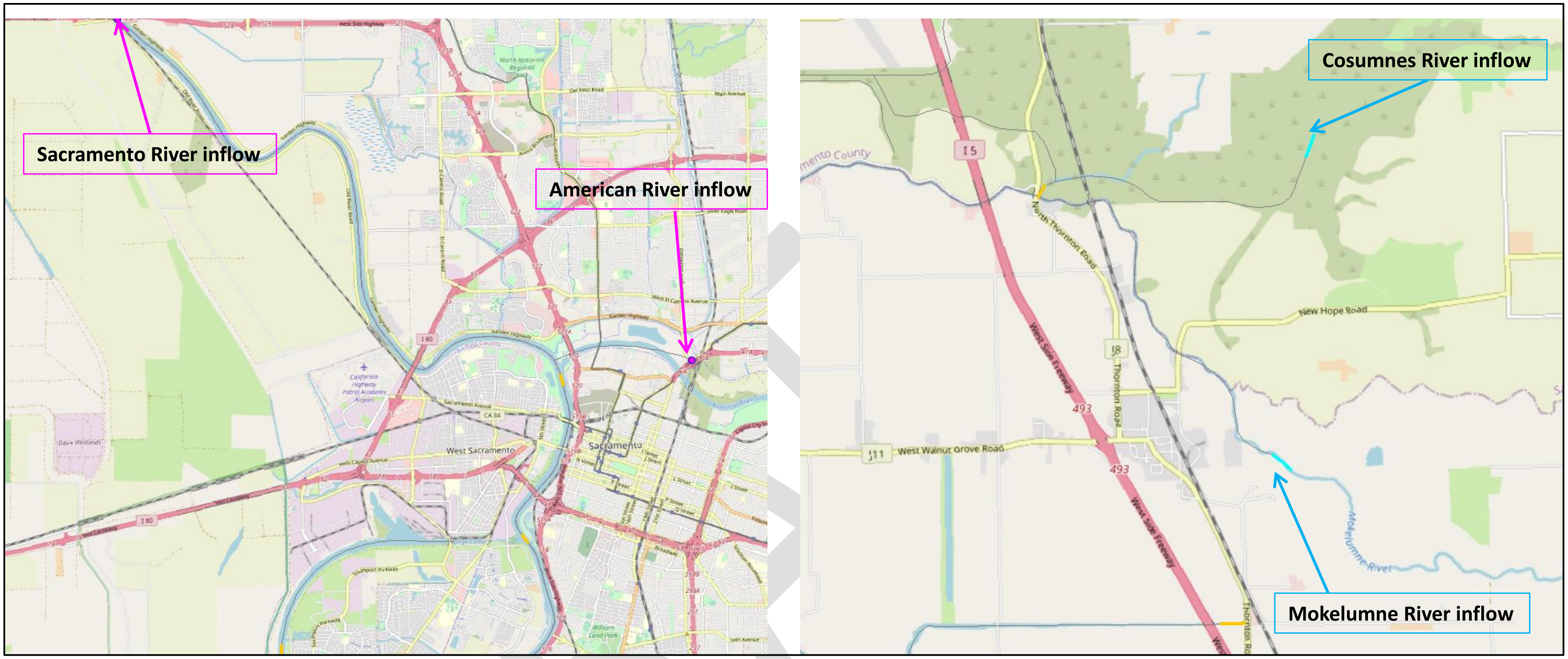


Figure 12 Inflow locations for the four relevant rivers in the RMA model grid.

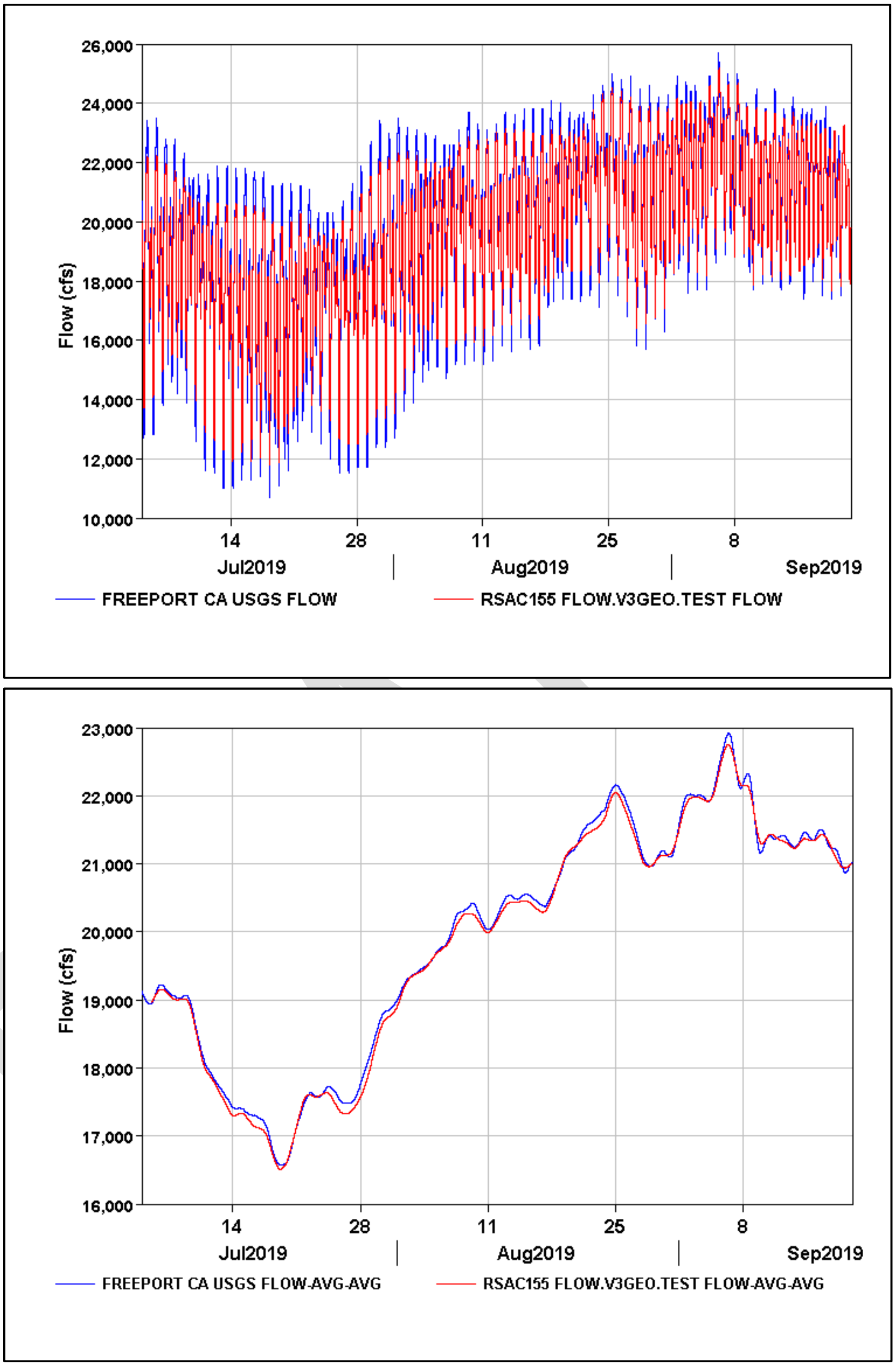


Figure 13 Comparison model RMA model flow (upper) and tidally-averaged flow (lower) output with data at the Freeport data location (blue lines) which is denoted RSAC155 in the model output (redlines).

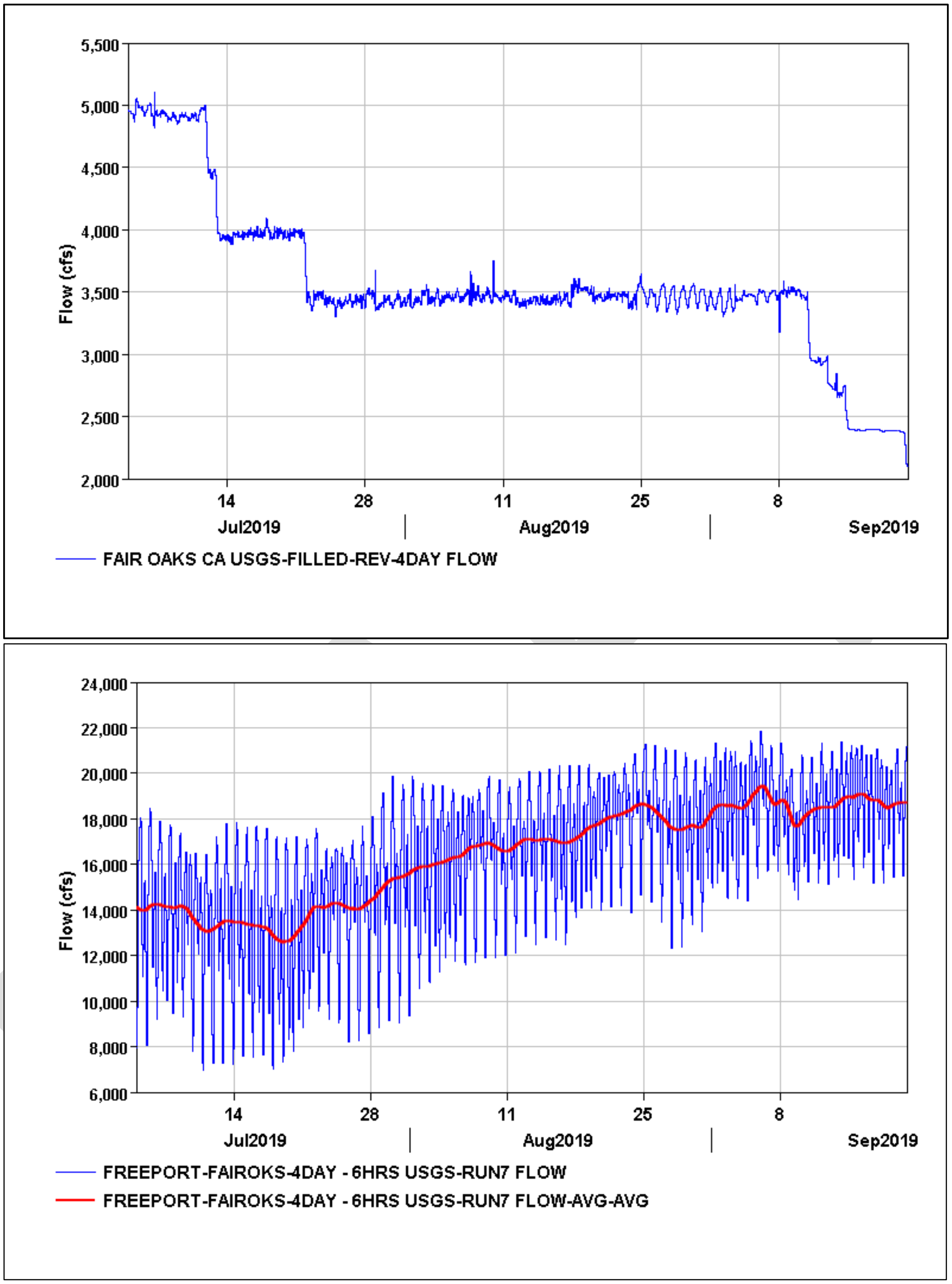
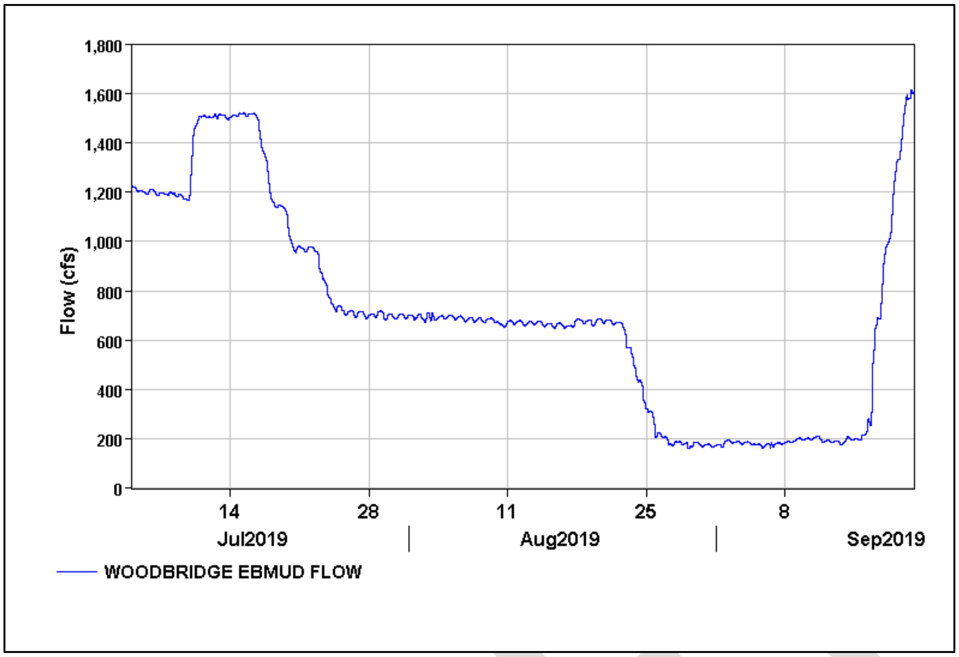


Figure 14 The upper figure shows the boundary inflow used for the American River. Because the Sacramento River inflow boundary is upstream of the American River, the American River flow was subtracted from the Freeport flow, which was time-shifted (blue line) and then tidally averaged (red line) for use at the inflow boundary (lower figure).



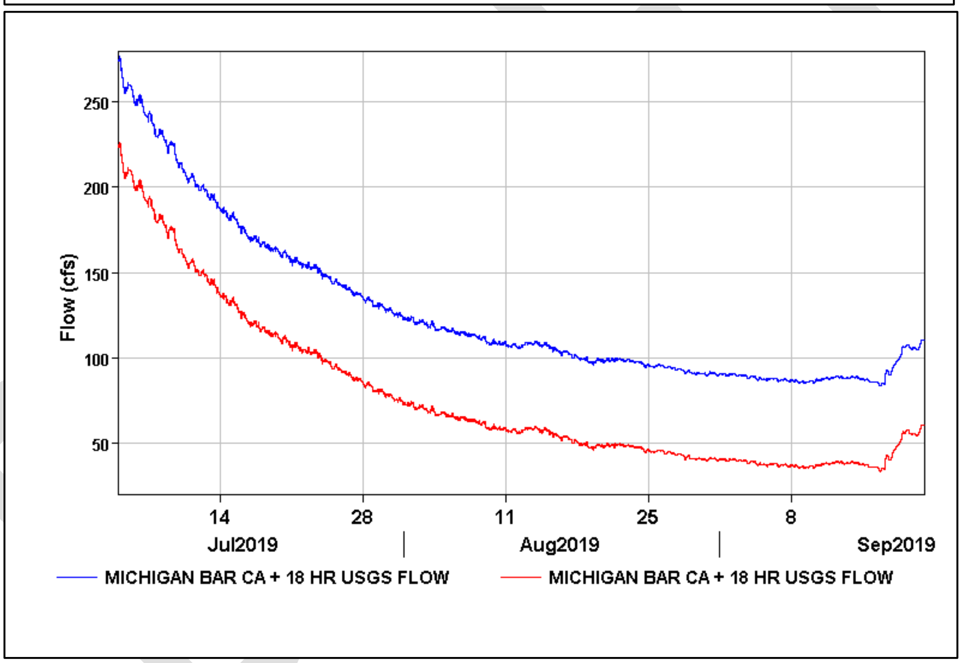


Figure 15 Data used as boundary inflow at the Mokelumne River boundary (upper figure) and at the Cosumnes River boundary. The boundary flow used for the Cosumnes River (blue line) was advanced 18 hours from the data at Michigan Bar and 50 cfs was added to the downloaded data to improve EC model results downstream on the Mokelumne River.

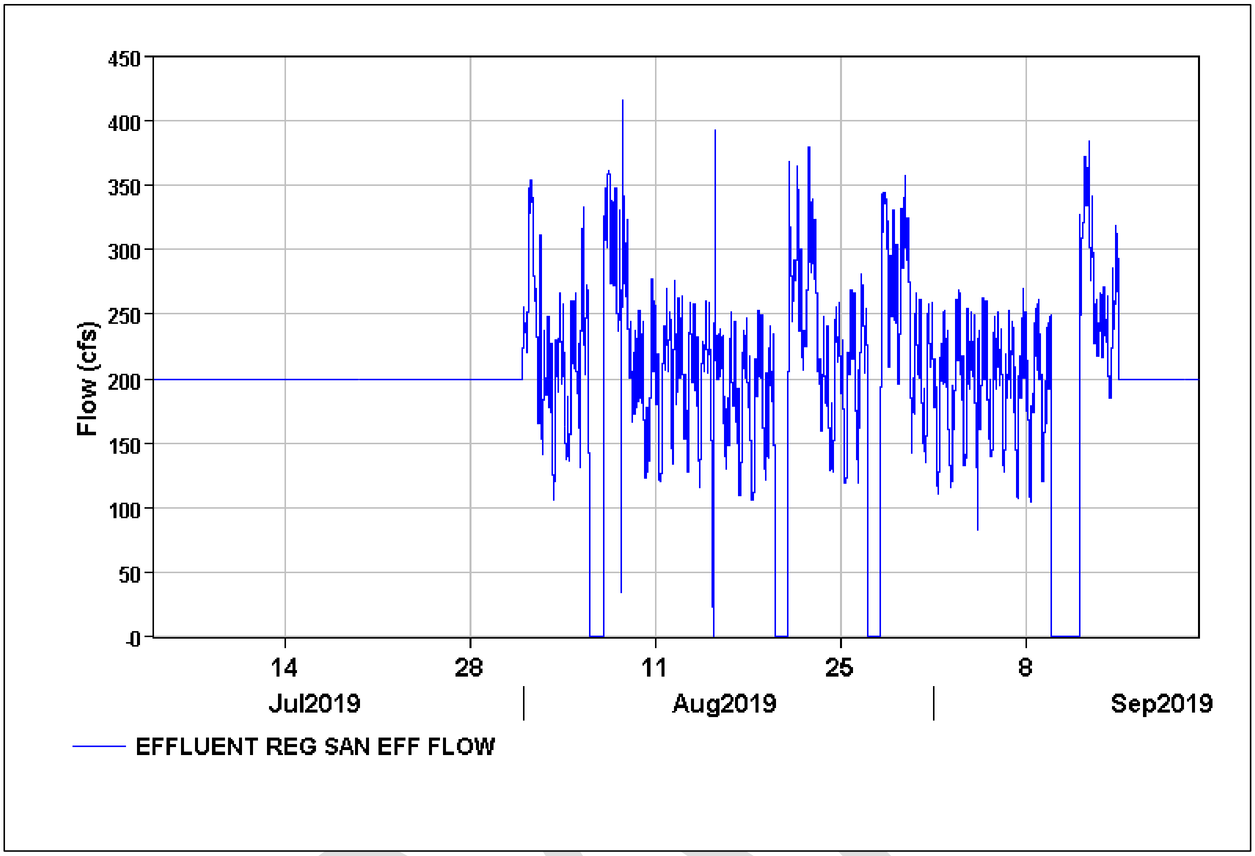
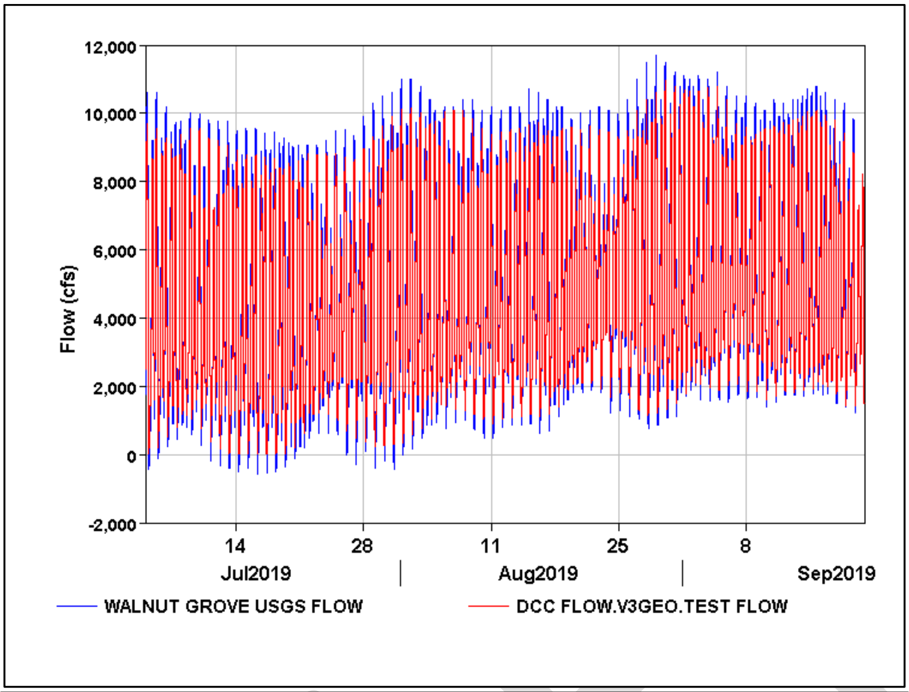


Figure 16 Effluent outflow from Regional San – where data was not available, flow was set 200 cfs. Sections of zero flow indicate time frames when effluent flow was briefly ceased. The final section of flow cessation occurred September 9 – 11, 2019, which encompassed the project experiment.



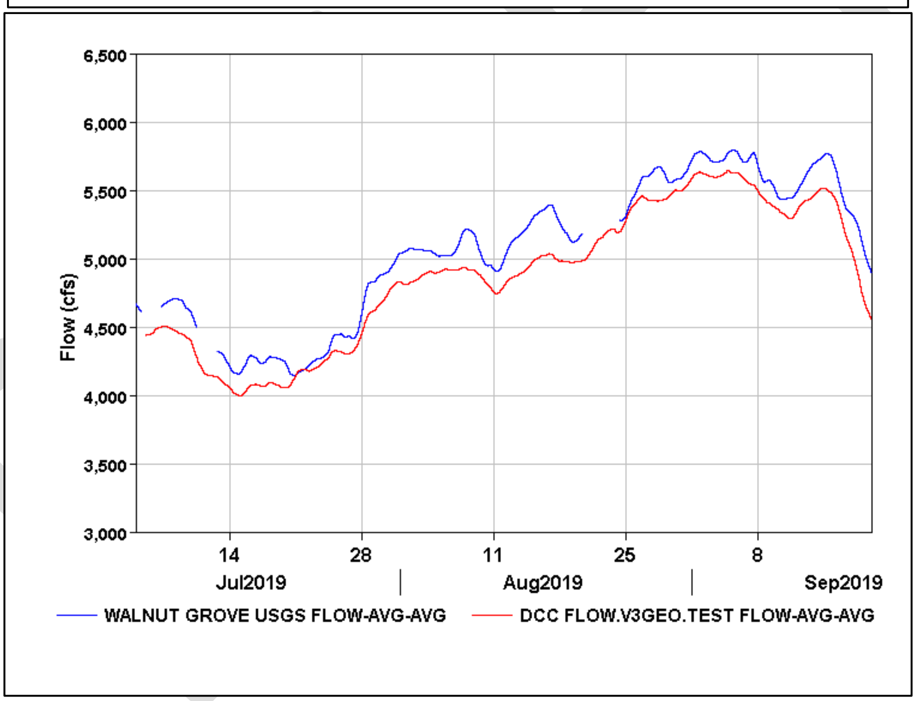
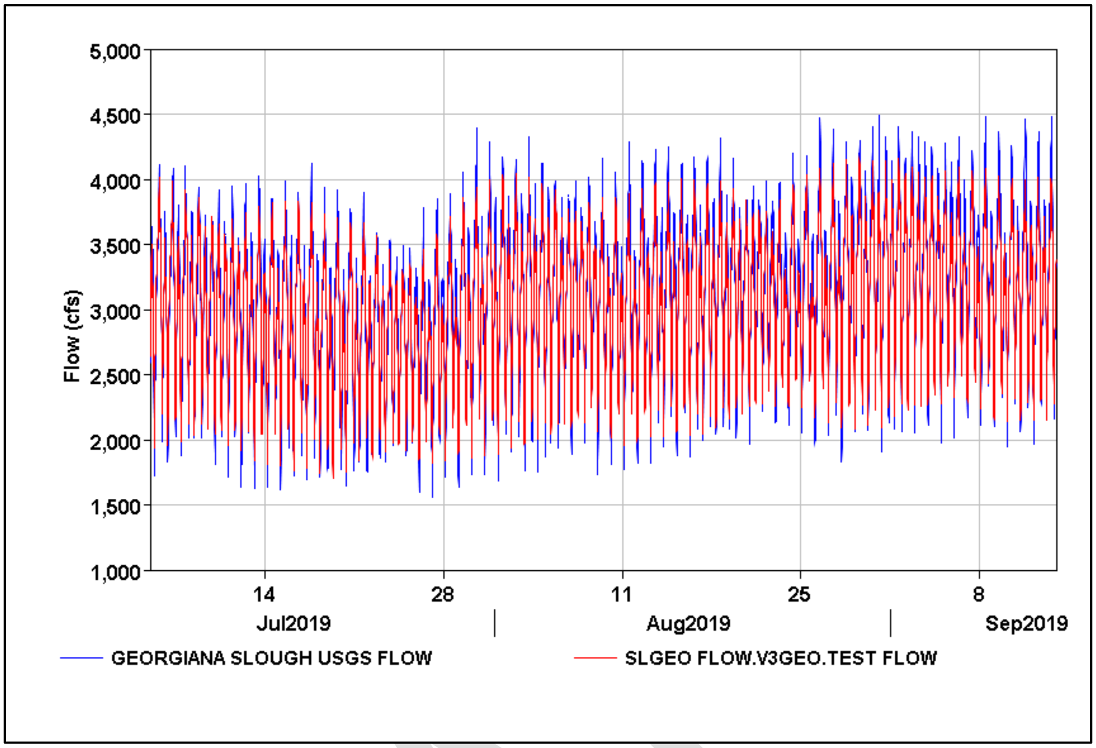


Figure 17 Data (blue lines) and model output red lines) at the Delta Cross Channel location for flow (upper figure) and tidally averaged flow (lower figure).



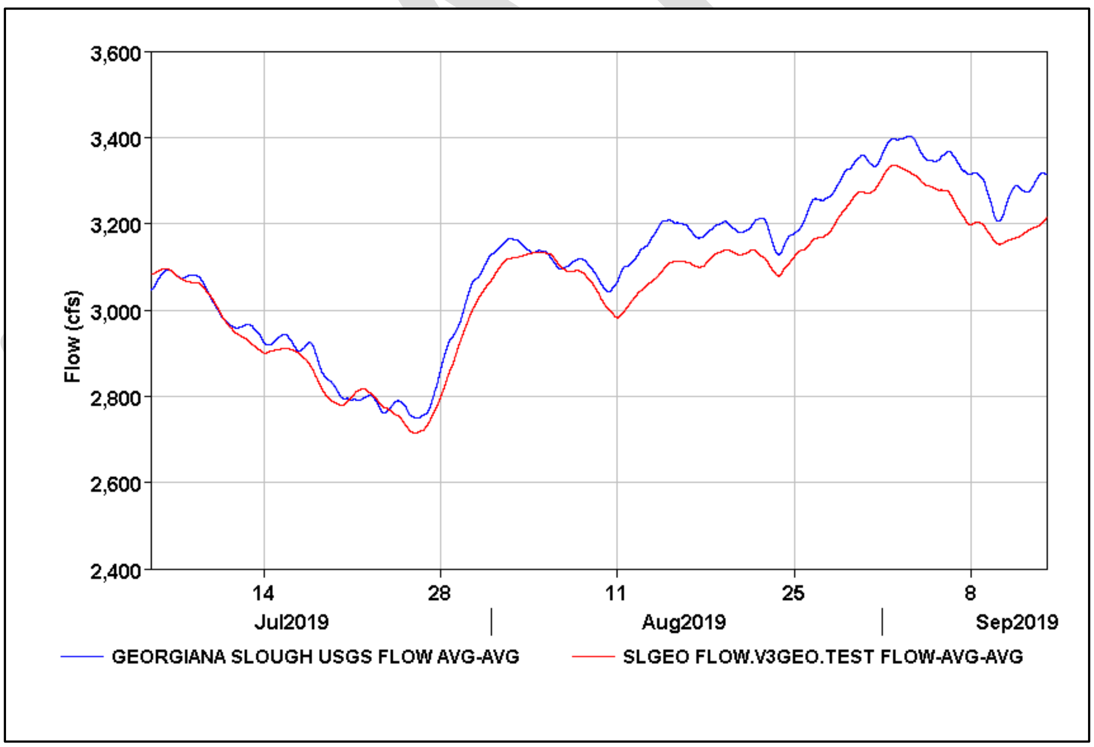


Figure 18 Data (blue lines) and model output red lines) at the Georgiana Slough location for flow (upper figure) and tidally averaged flow (lower figure).

Section 4 Development of Volumetric Simulations

RMA11 Dispersion Parameter Calibration Using Electrical Conductivity (EC)

The RMA11 EC model was used to provide the template for calibrating the dispersion parameters used in transport model volumetric simulations. EC behaves like a conservative tracer so this strategy produced an appropriate result for setting dispersion parameters for application in volumetric simulation. EC data availability from standard sources for boundary conditions and several downstream locations was acceptable in the time frame of interest.

EC data to check the accuracy of the model was obtained from USGS project measurements, other project data and from standard online data sources (CDEC, USGS). The RMA11 model dispersion parameters were fine-tuned to closely match EC measurements for the period 08-09/2019, focusing on the days when measurements were being collected for the project, September 09 – 12, 2019. Input of EC from DICU sources was not included as DICU flows were not included in the flow model. This omission required a 12 mS/cm (equivalent to UMHOS/CM shown in some figures) increase in the Sacramento River EC inflow. Note that the EC of effluent from Regional San was only available from a sparse data set which formed an additional source of uncertainty in the development of EC boundary conditions and therefore in the values set for dispersion parameters.

Refinement of the EC model boundary conditions and parameters began once the RMA2 flow model for the period July-September, 2019 was judged sufficient (i.e., flow and stage output compared well to data). Regional EC calibration consisted mainly of refining the dispersion parameters values and spatial distribution, as well as changes in Regional San effluent flow and EC timing and magnitude during periods without data. Figure 19 documents the EC boundary condition for the Sacramento River – as implemented for the flow boundary, the EC time series was shifted in time. The EC was uniformly increased by 12 mS/cm to better match the data at Freeport – as mentioned above DICU flow or EC contributions were not included in the model setup. Figure 20 documents the EC boundary condition for Regional San effluent – the times where data was missing were estimated – effluent flow was ceased September 9-11, 2019 so there was no EC applied. EC at the American, Mokelumne and Cosumnes Rivers was set at a constant 40 mS/cm.

Figure 21 illustrates that cessation of effluent flow results in a measurable decrease of EC at downstream locations, although delayed in time due to transport in the river flow. Figure 22 shows model results in comparison with data at three locations within and just downstream of the project area, while Figure 23 shows a shorter time frame comparison view in September 2019 at Freeport and the DCC. Note the dispersion parameter calibration shows the transport model was very good for timing and for magnitude at these locations, although low by a couple of mS/cm at the peaks.

The most difficult region for setting dispersion parameters consisted of the channels and rivers downstream of the Delta Cross Channel and especially at the split of the Mokelumne River into North and South branches. Except for USGS project measurements, no time series were available for comparing model output to measured data. Through multiple iterations of changes to dispersion parametrization, the output from these simulations was compared to project measurement data from the USGS and Regional San to test model consistency in timing and magnitude. As a final step to improve this consistency in the region of the Mokelumne River split, the Cosumnes River inflow was increased by 50 cfs (see Figure 5) – this change was felt reasonable as a reliable downstream measurement of Cosumnes River flow was not available.

Modeled EC for the final RMA11 simulation (name: ECTest.M5V3F2) was compared to measured EC data in several ways. In addition to the downloaded EC timeseries data shown in Figure 21 through Figure 23, USGS point EC data measurements from their high frequency data acquisition on September 09, 10 and 11, 2019 were used to compare named model output locations to these GPS data locations. USGS data was plotted in Google Earth, and the data measurement times and locations were compared to the corresponding model output locations. These results are compiled in an EXCEL file (USGS.highfreqEC.vs.modelEC.xlsx). For each day, an example figure is included to illustrate the methodology.

Data from Regional San's transect data acquisition on September 11th 2019 was analyzed at named locations (see Figure 24) and EC data plotted (file MG.Transect.regsan.analysis.xlsx). This data was used in two ways to "ground truth" the calibrated RMA11 EC model. For selected locations, the difference between the modeled EC at the EC measurement time was calculated. In these 20 locations, the difference between the values ranged between -5.8 and 4.2 mS/cm (file Compare.rmamodelEC.regsan.transect.xls). Also, the volumetric percentages by source at selected named locations was multiplied by the boundary condition ECs to check the reliability of the volumetric measurements (file: RMA.ECandVolume.regsan.data.Calculations.xlsx).

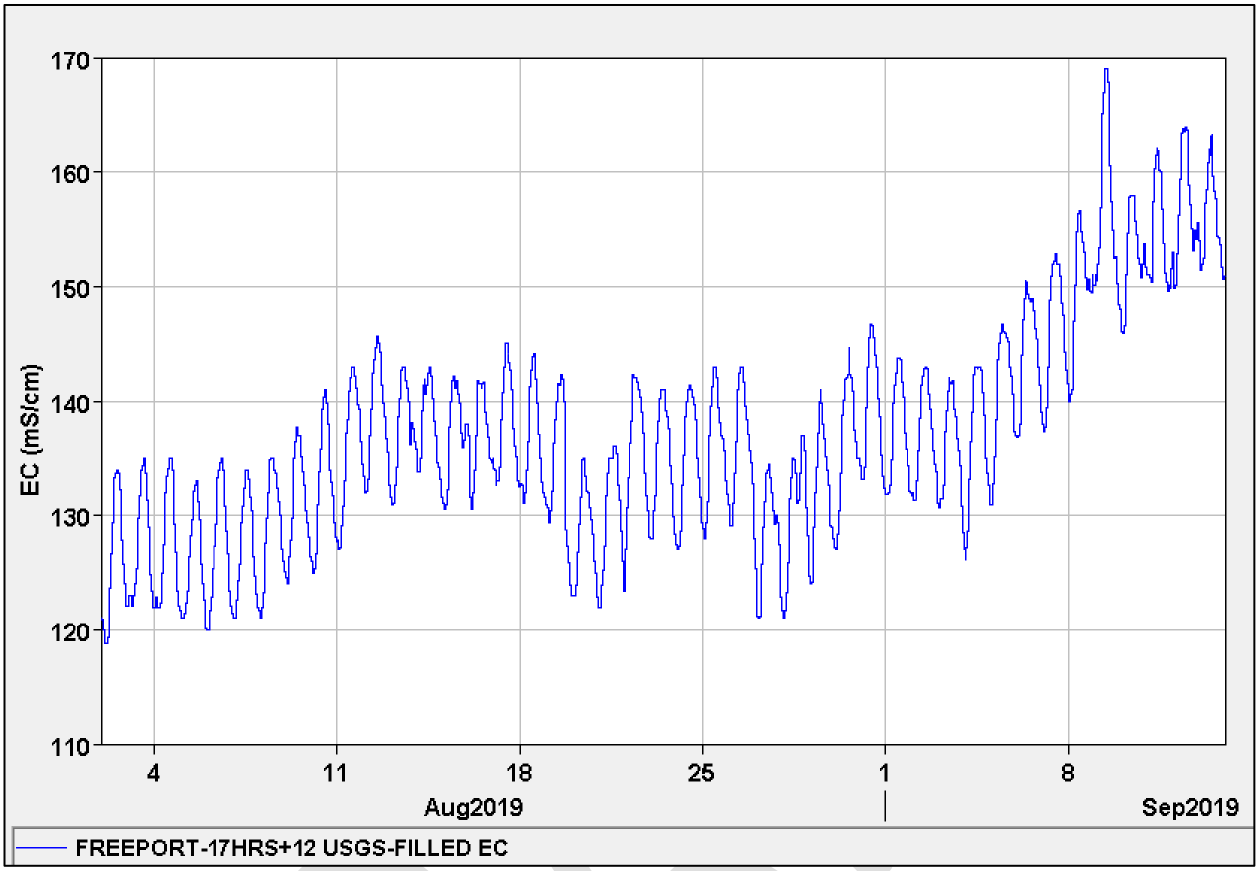


Figure 19 Sacramento River EC boundary condition.

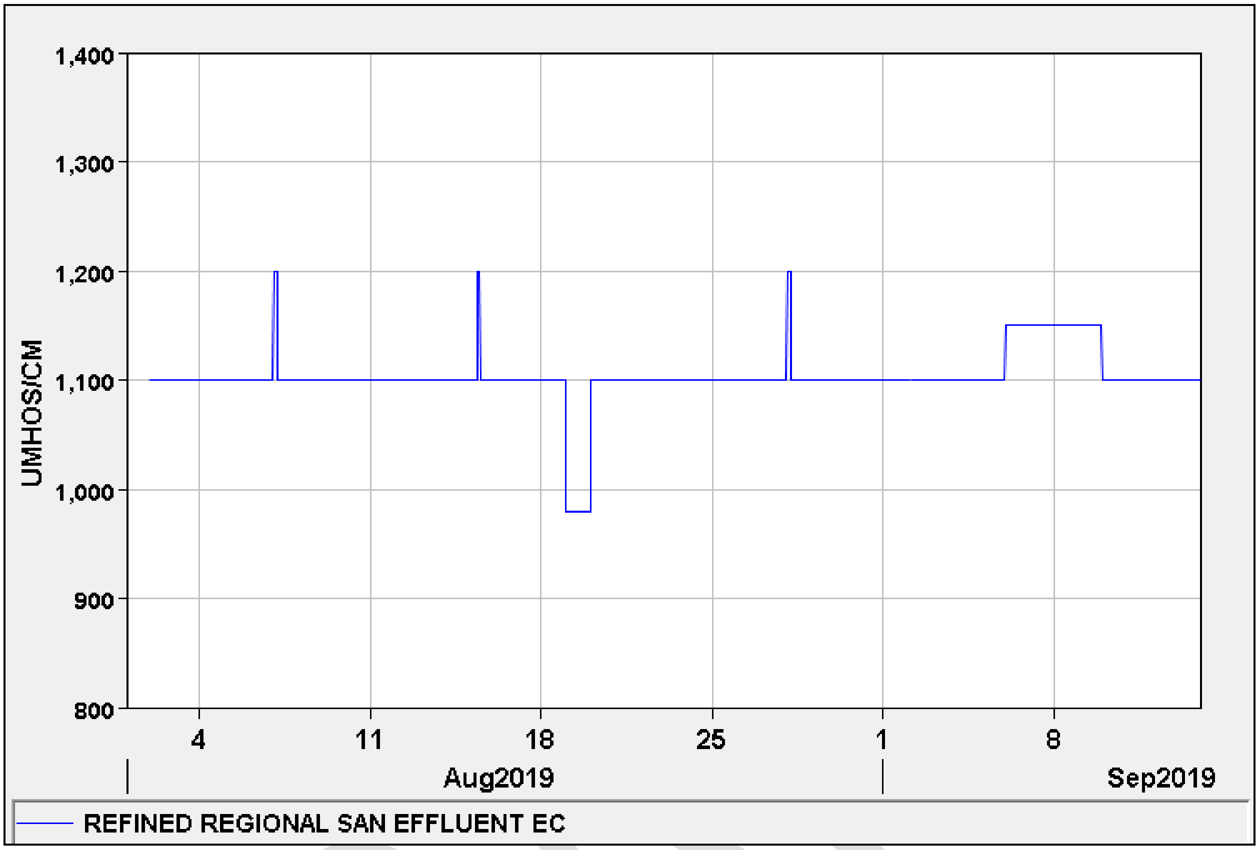


Figure 20 Regional San effluent EC boundary condition.

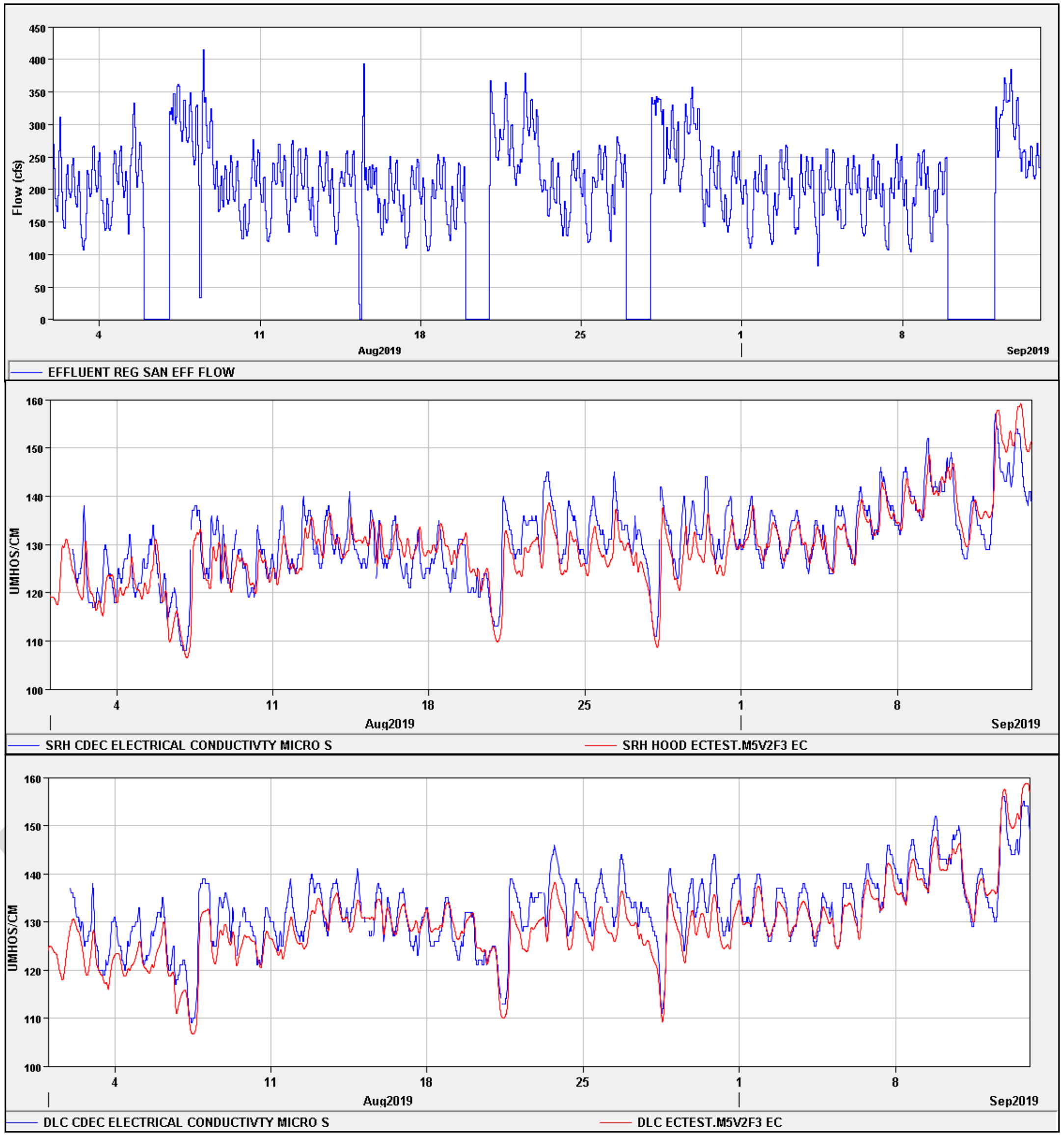


Figure 21 Effect of ceasing Regional San effluent flow (top panel) on EC at Hood (center panel) and in the DCC (bottom panel) for data (blue line) and model output (red line).

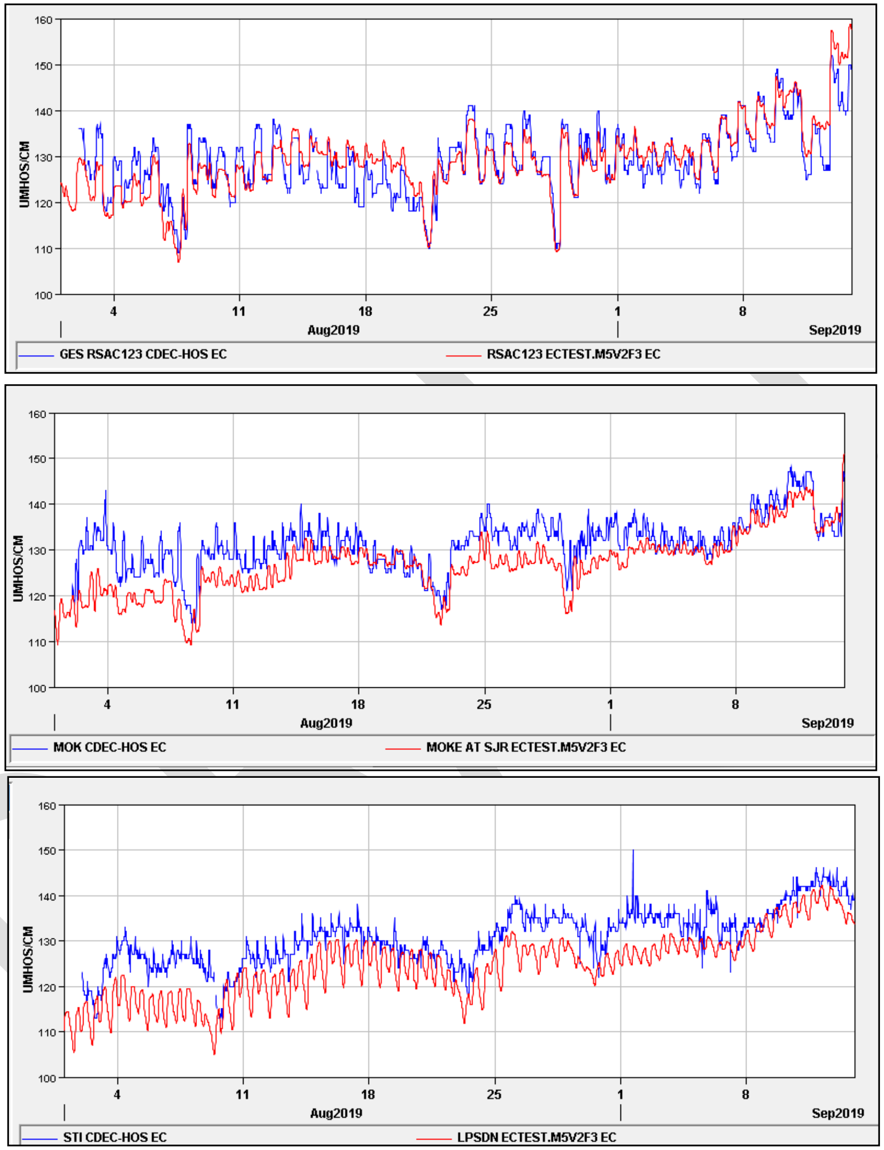


Figure 22 EC on the Sacramento River at RSAC123 (top panel), downstream on the Mokelumne River near the San Joaquin River(center panel), and at the southern end of Staten Island on the South Fork of the Mokelumne River (bottom panel) for data (blue line) and model output (red line).

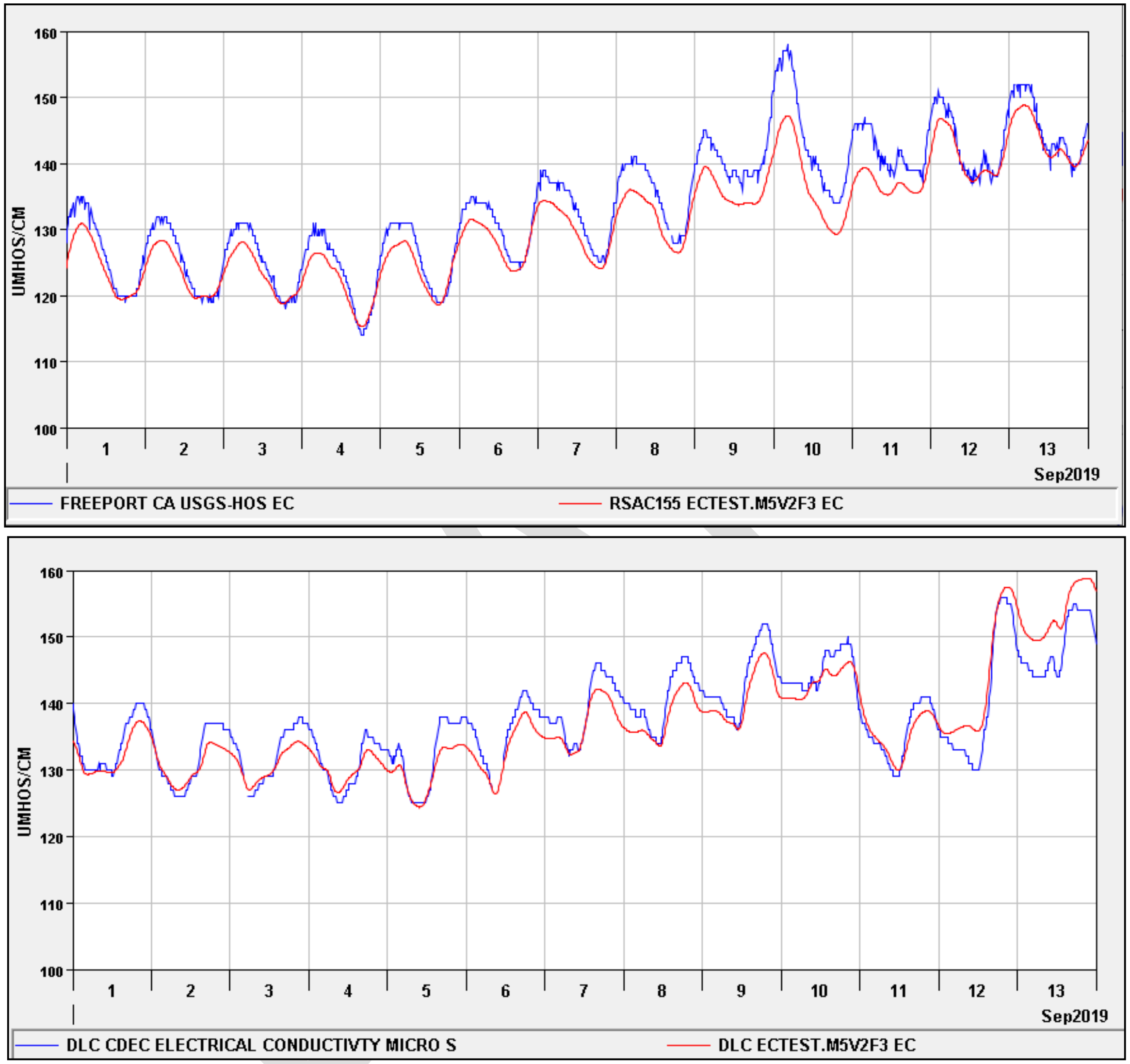


Figure 23 Detail view of EC at Hood (top panel) and in the DCC (bottom pane) at model output location DLC for data (blue line) and model output (red line) in September, 2019.

Volumetric Simulation Results

Volumetric modeling output was calculated using the RMA11 transport application with updated dispersion parameters described in the previous section on RMA11 dispersion calibration. The volumetric simulations were set as follows:

1. The boundary conditions for the American and Sacramento Rivers were combined and set to 100.
2. The boundary conditions for the Mokelumne and Cosumnes Rivers were combined and set to 100.
3. The boundary condition for Regional San was set to 100 – note that Regional San inflow was stopped for 2 days during the experiment, so there was no contribution during this period.

Model output from each of these three simulations gives the volumetric percentage, which is also interpreted as the mixing percentage, of each of the combined sources at downstream locations. Time series of the numerical output is provided at selected project measurement locations is include in figures below. Figure 24 shows the locations specified by Regional San, while Figure 25 and Figure 26 show these output locations in screen captures of the RMA grid. A separate EXCEL file with model output time series results at all locations is included with project documentation (VOLUMETRIC.OUTPUT.xls).

Figure 27 shows the downstream location MOKEM is tidally influenced in the model, with the majority source alternating between the combined Mokelumne-Cosumnes source and the combined Sacramento-American source. Figure 28 shows that a small percentage of Regional San effluent tidally mixes with Sacramento-American source at the RSAC155/Freeport location, while a somewhat larger percentage is present at the SREM location in Figure 29.

Mixing on the South Fork Mokelumne was complicated and heavily influenced by tidal period as shown in Figure 30 and Figure 31. In Figure 30. The mixture at the SMR location on the south fork of the Mokelumne is dominated by alternating between the Sacramento-American or Mokelumne-Cosumnes sources with a minor contribution from Regional San effluent. Three locations (left, center and right) across the river at this location with a two-dimensional grid are shown to have variable mixing percentages from the three sources in Figure 31.

Figure 32 shows the variation in the three separate inflow sources at NMR on the north fork of the Mokelumne River. Figure 33 shows the change in tidal signature for the three sources at SMR and SFM4, from north to south along the south fork of the Mokelumne River. Figure 34 shows the shift from north to south along Georgiana Slough, from GS1 to GS4, presents primarily as a shift in timing.

The volumetric output from the three-combined-source volumetric transport model was used to perform an inter-model compression of the two RMA11 transport models EC model boundary condition EC to test the validity of the source percentages calculated in the volumetric models. Using model output at six named locations (see Figure 24), the three modeled percent volumes at that location and time were used along with the associated boundary condition EC to calculate the corresponding EC to compare with the measured data. In each case, the modeled EC and the EC calculated with volumetric percentage and boundary condition EC matched within 2 mS/cm, as expected.

NOTE: *three movies were prepared for internal use by project partners showing modeled percentages for each combined source during the study period – a color scale is used to visualize the percentage spatially and time-specific values are shown at selected locations. These movies were used to QA/QC the volumetric models and for use during project meetings by the project members to assist in the interpretation of tidal influences on source mixtures during the study period. These movies are not currently included in deliverables.*

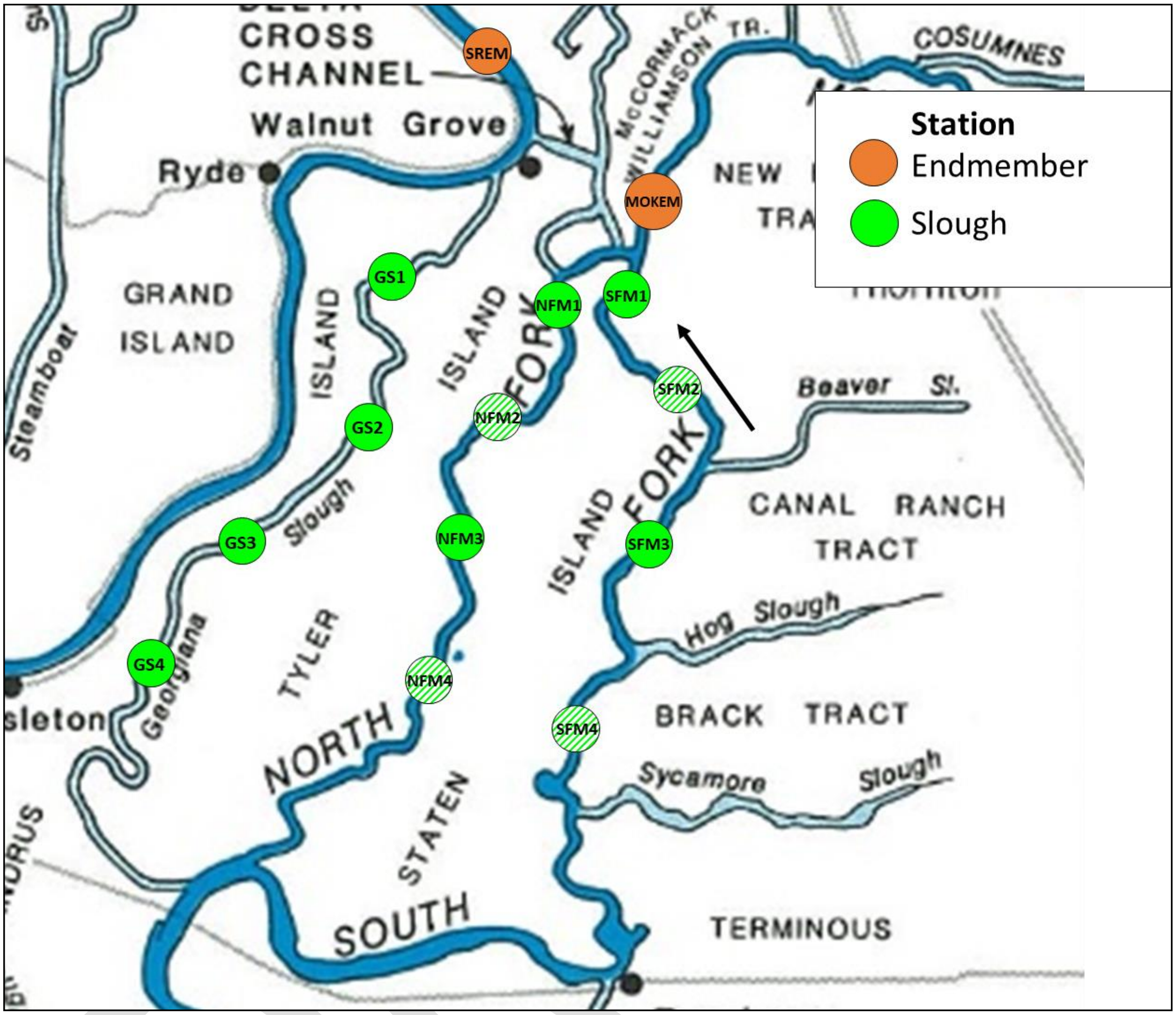


Figure 24 Model output locations for volumetric time series – figure supplied by staff at Regional San.

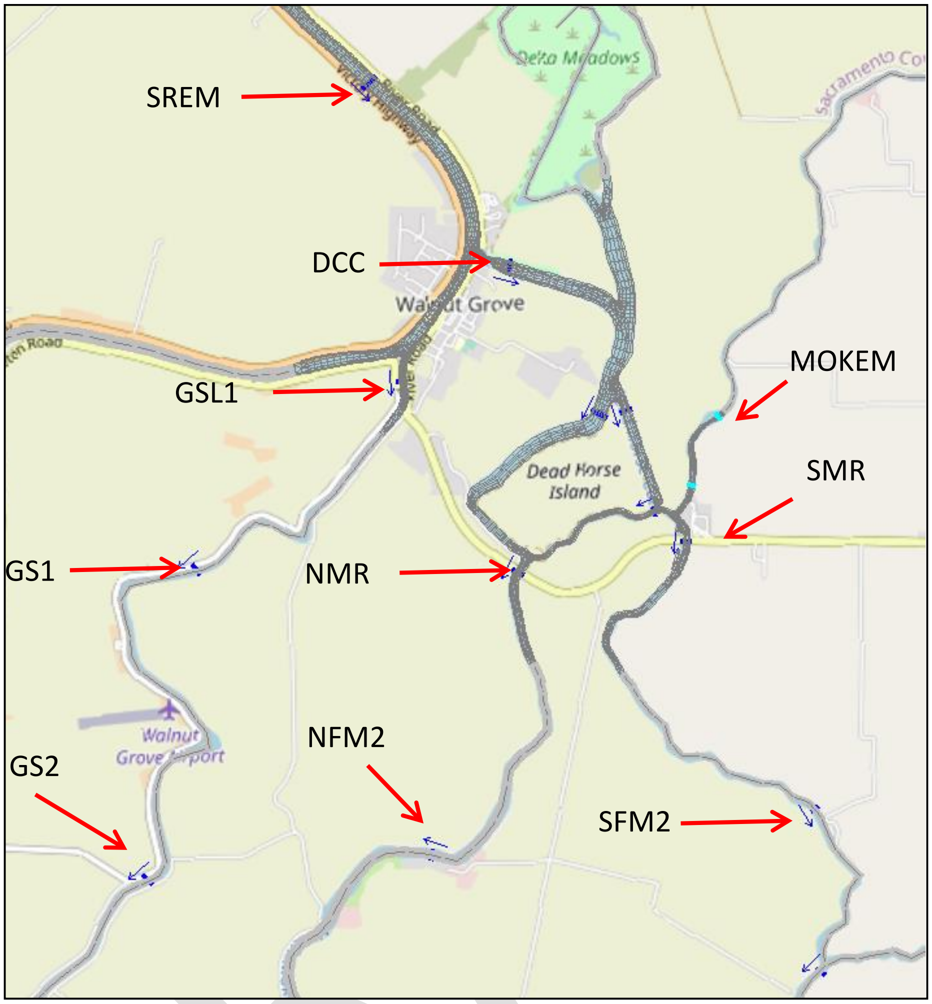


Figure 25 Nomenclature and location for particle tracking and volumetric output in upper portion of study area.

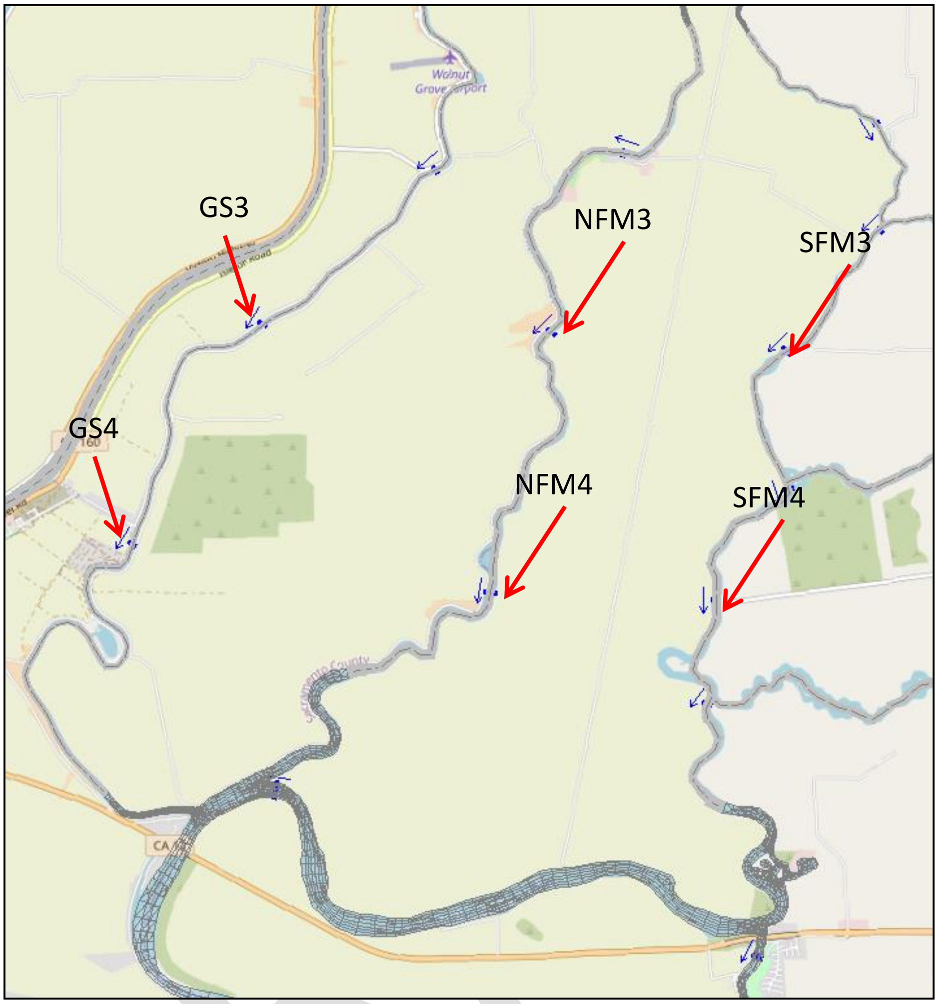


Figure 26 Nomenclature and location for particle tracking and volumetric output in lower portion of study area.

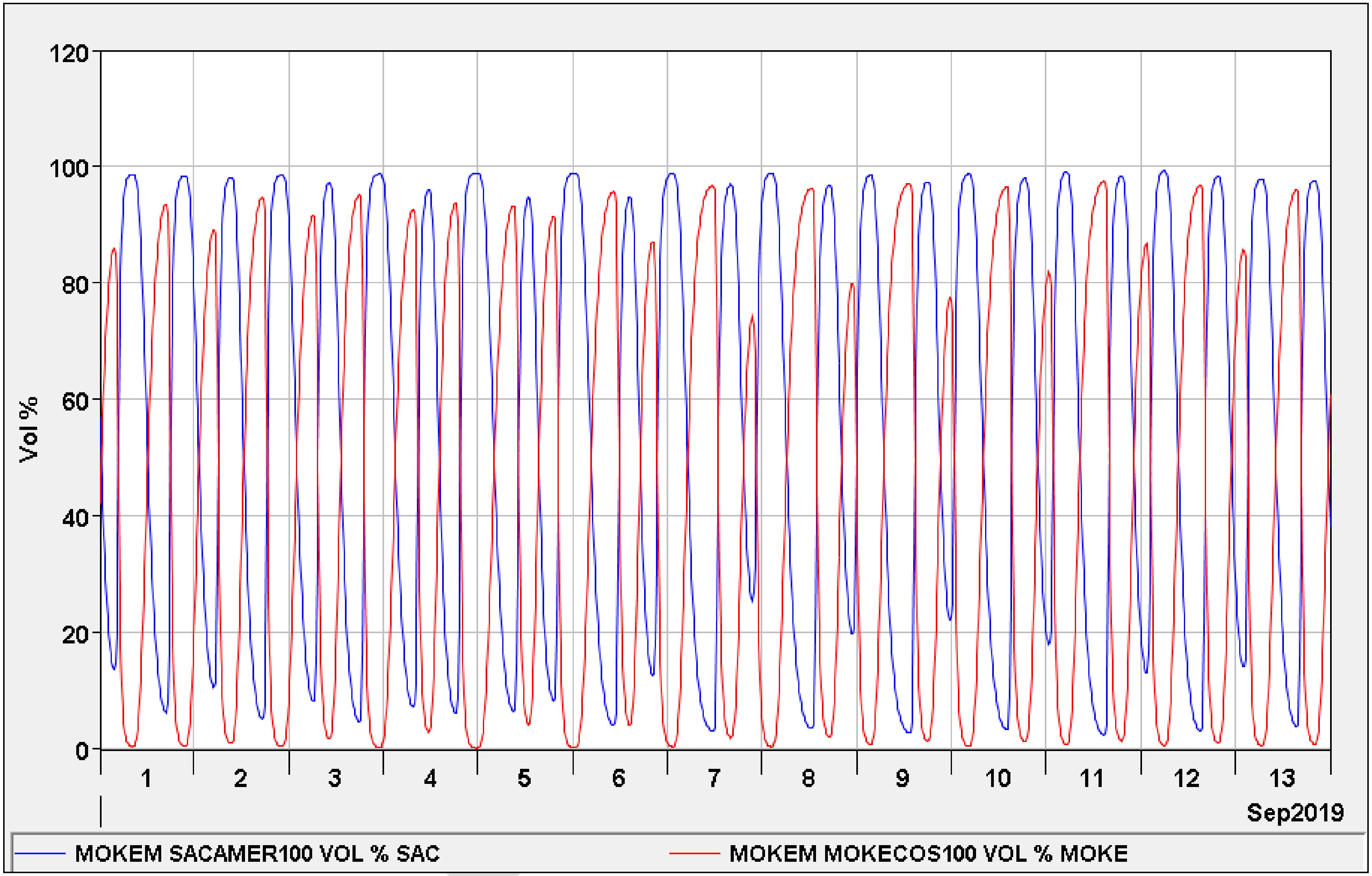


Figure 27 Volumetric percentages by source at the boundary location on the Mokelumne River

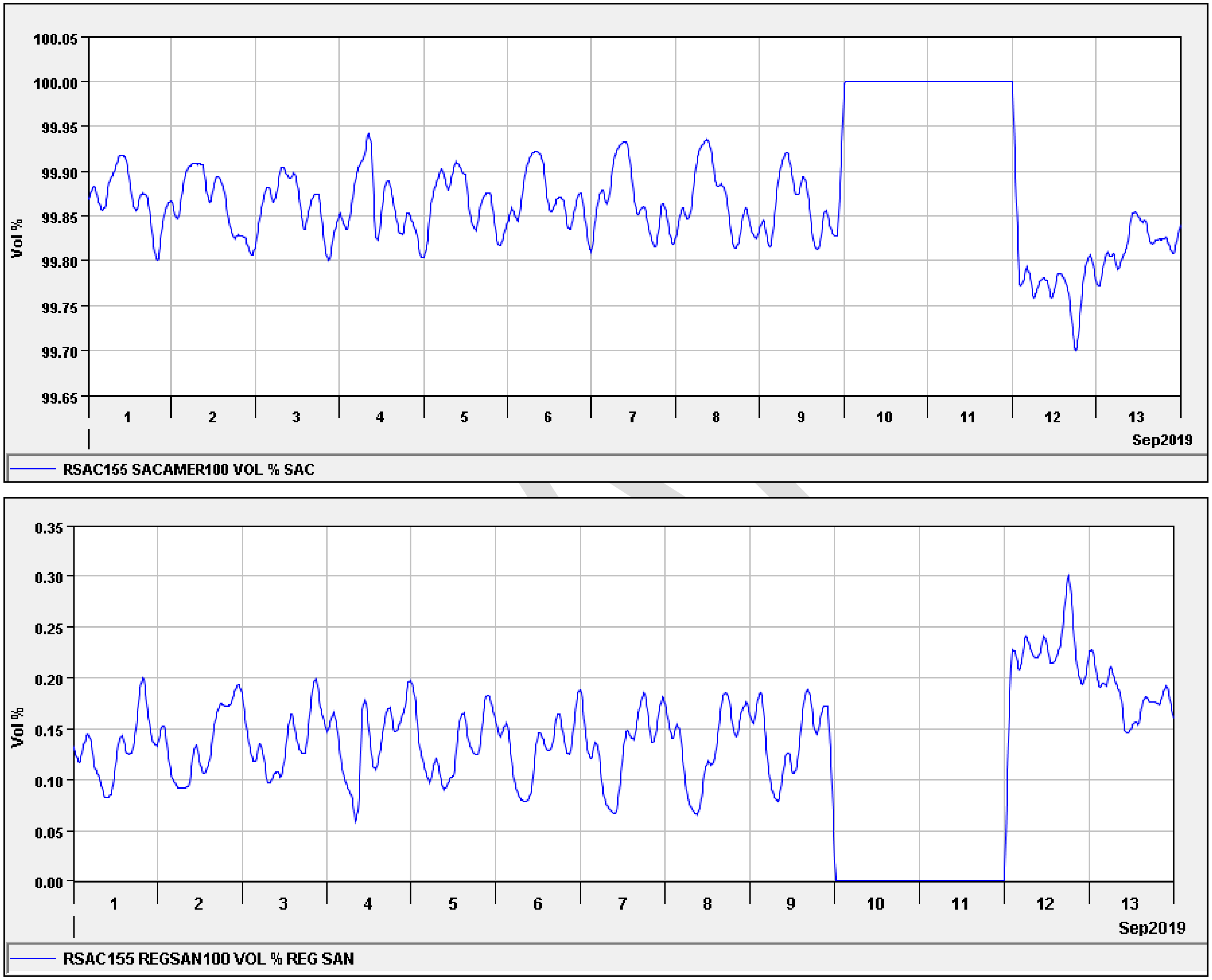


Figure 28 Volumetric percentages by source at RSAC155 on the Sacramento River.

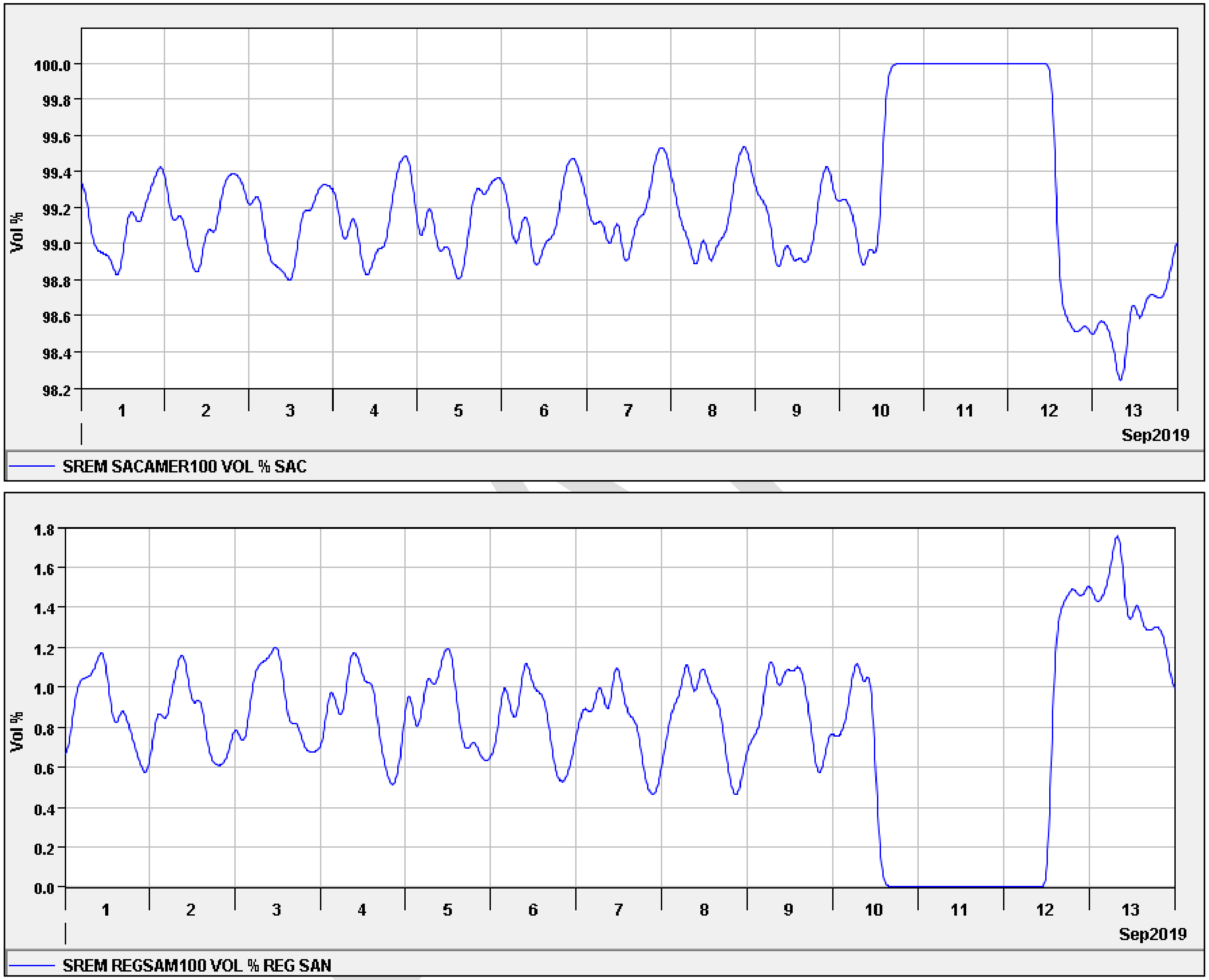


Figure 29 Volumetric percentages by source at model output location SREM on the Sacramento River.

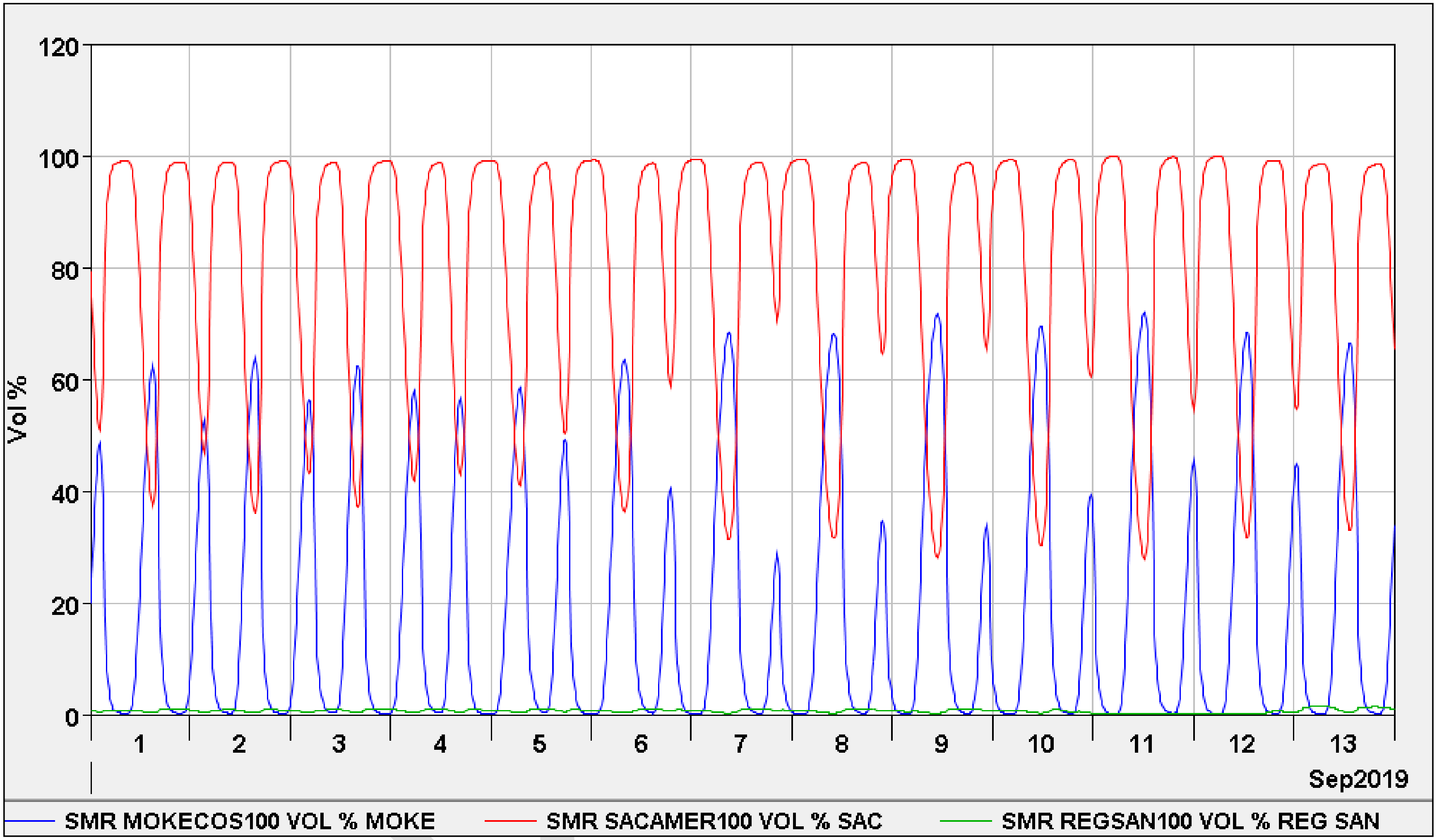


Figure 30 Volumetric percentages by source at model output location SMR on the South Fork of the Mokelumne River.

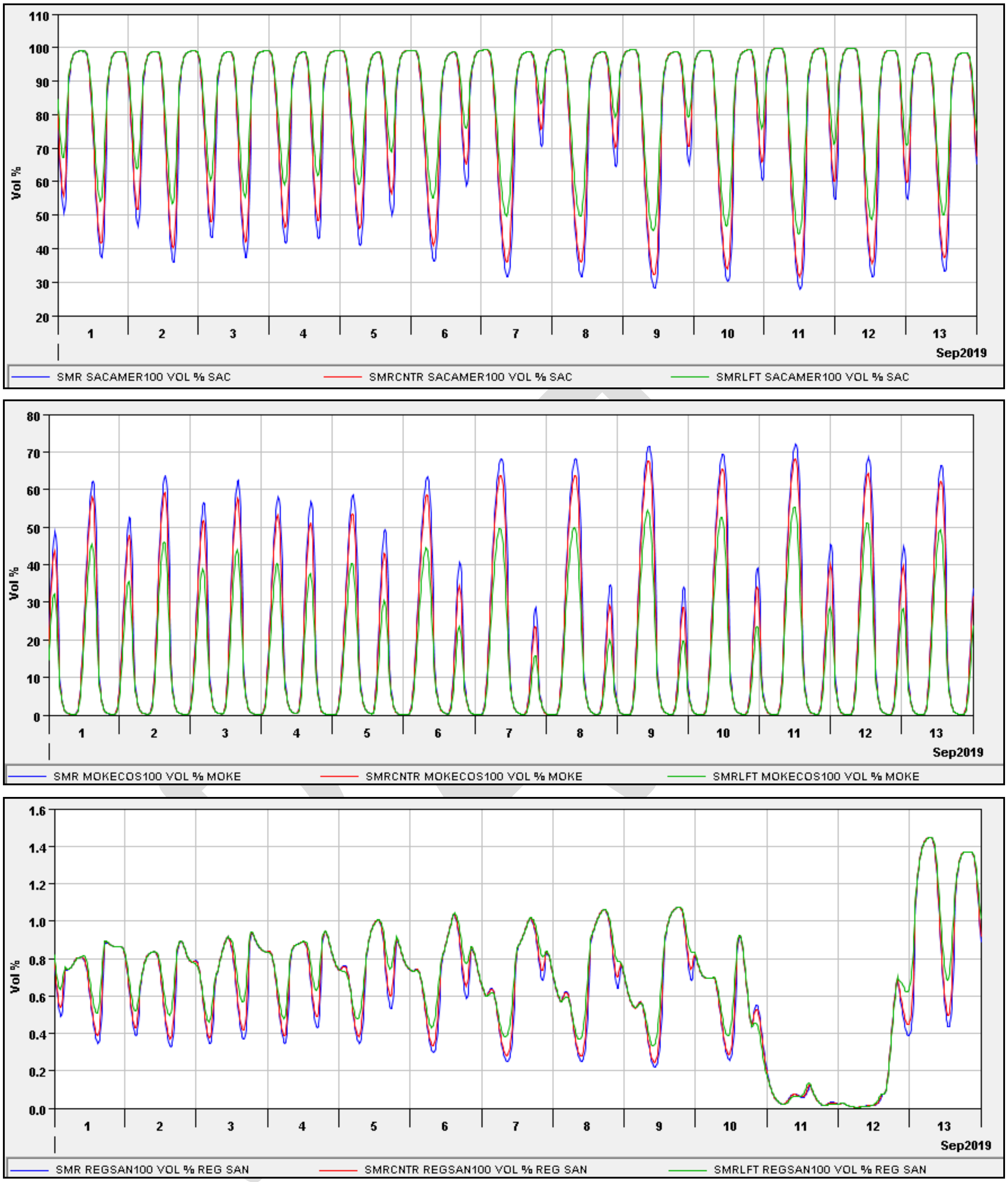


Figure 31 Volumetric percentages of the three sources at model output location SMR on the South Fork of the Mokelumne River illustrating variation across the river in transect.

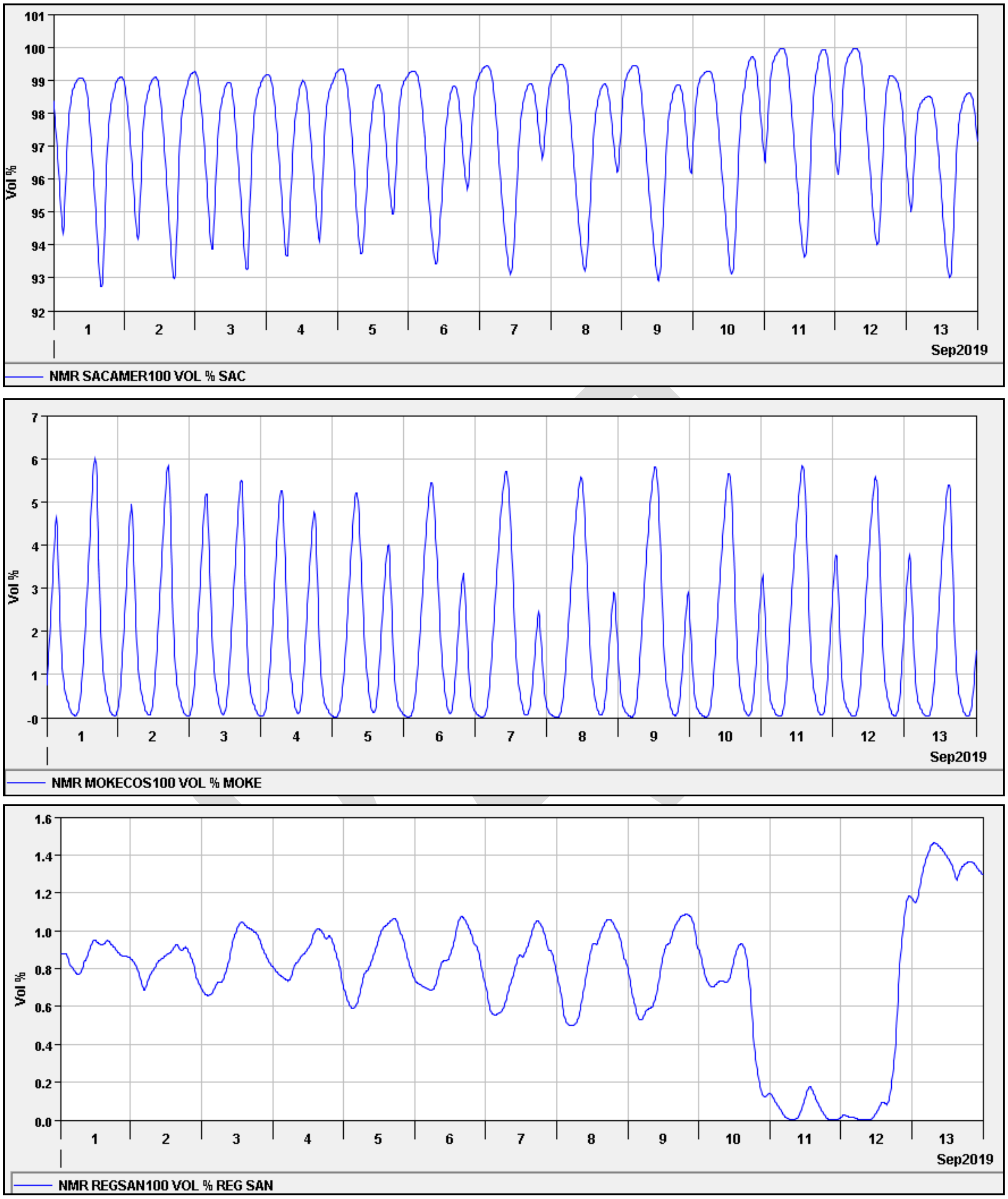


Figure 32 Volumetric percentages of the three sources at model output location NMR on the North Fork of the Mokelumne River illustrating variation across the river in transect.

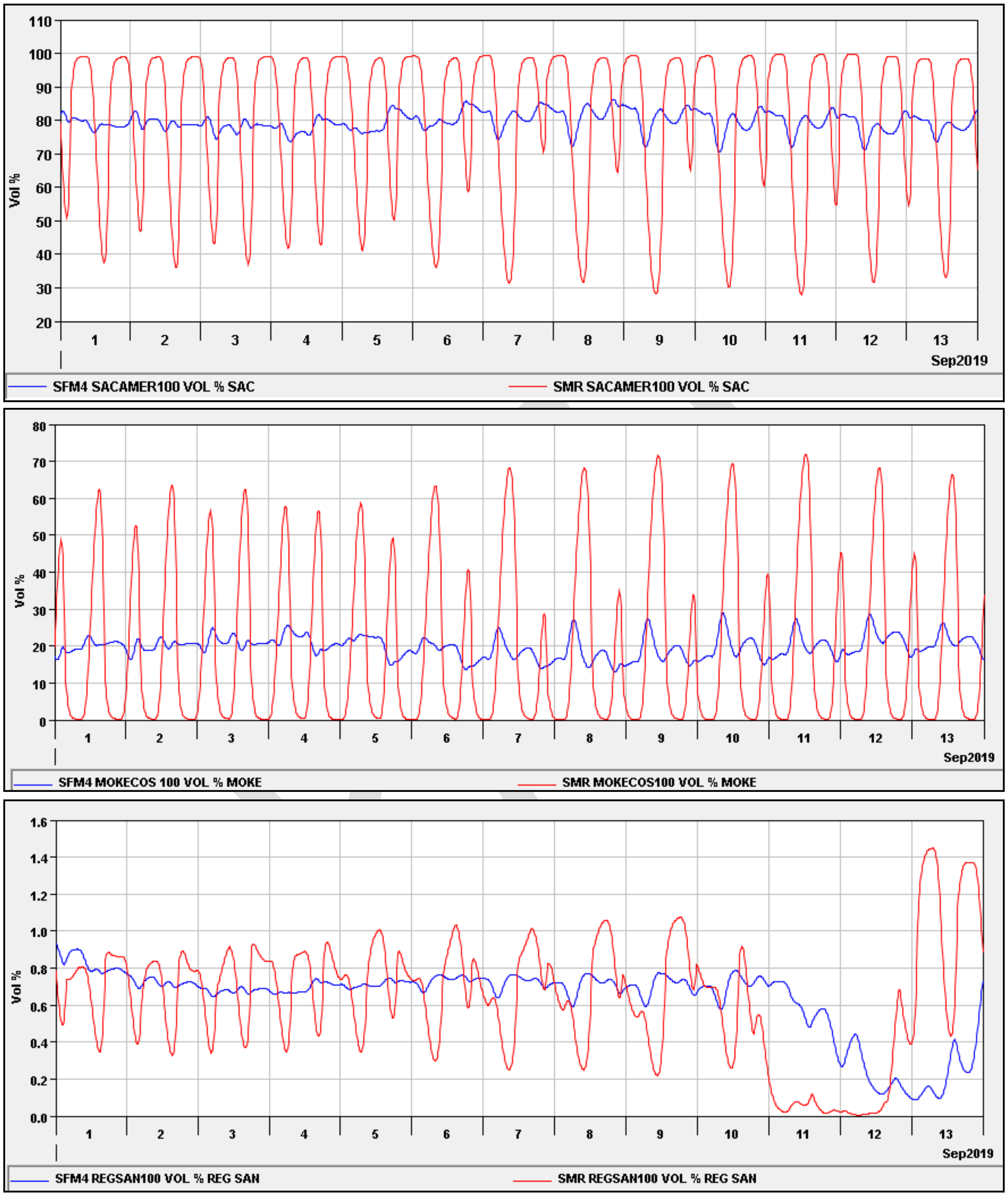


Figure 33 Volumetric percentages of the three sources at model output locations SMR and downstream at SFM4 on the South Fork of the Mokelumne River illustrating variation from north to south down the river.

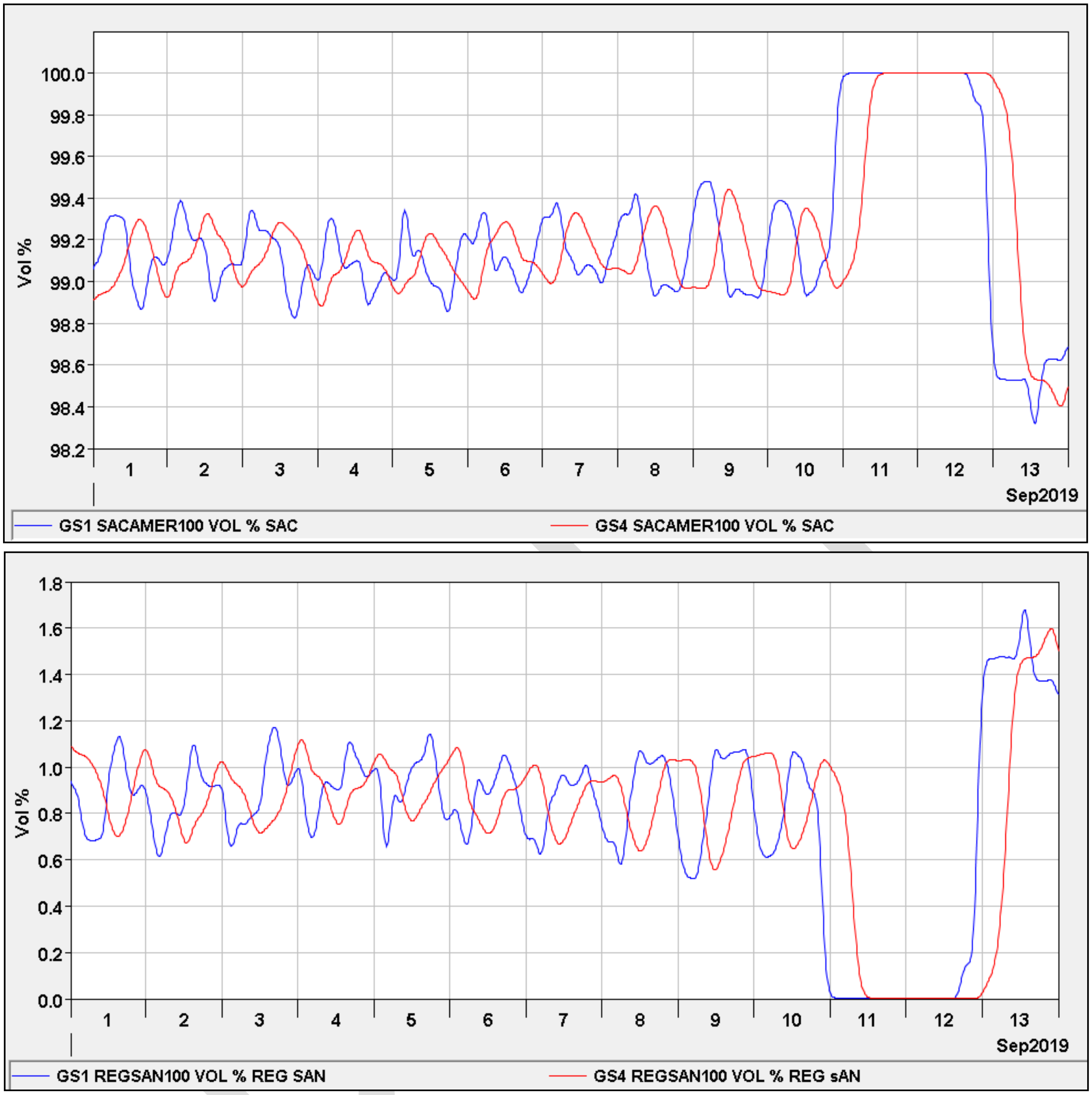


Figure 34 Volumetric percentages of two sources at model output locations GS1 and downstream at GS4 on Georgiana Slough illustrating variation from north to south down the slough.

Section 5 Particle Tracking Simulations

Using the flow model developed for the study period described above (Section 3), particle tracking simulations and movies were developed to help characterize the movement and mixing of water parcels during the study. The particle tracking code used the output of the RMA2 flow model in its calculations. In general, dispersion values for the particle tracking simulations are set by the user. For this study, no dispersion values were set for the particle tracking as dispersion settings developed during the EC calibration indicated a level of complexity beyond any attempt for justification in particle tracking. Output from particle tracking simulations is used by the project participants to assist in the interpretations of sample measurements. Two movies were prepared for the project participants emphasizing aspects of the flow dynamics using the procedure described below. These movies are included in a separate PowerPoint file as part of RMA's project deliverables.

Three particle sources of different colors were inserted in the model grid near the location of the Regional San effluent outflow location (Figure 35, right hand figure), each of which inserted 100 particles/minute during portions of the simulation period (02 – 13 September, 2019). Particles numbers do NOT represent any flow or load criterion – instead these values were selected to make visualizations understandable/comprehensible and so have no physical significance. Bright red particles represent Sacramento River water parcels which includes Regional San effluent before the shutdown (i.e., insertion stopped when the effluent flow stopped), bright blue particles represent Sacramento River water parcels without Regional San effluent ONLY during the effluent flow shutdown, and darker red particles represent Sacramento River water parcels which includes Regional San effluent ONLY after the shutdown.

Cyan particles represent water parcels originating from the Mokelumne River – they were inserted at a rate of 4 particles/minute at the downstream insertion location and 1 particle/minute at an upstream location on the Mokelumne River (Figure 35, left hand figure). Using two locations improved the quality of the visualizations but had no other significance.

Figure 25 and Figure 26 identify the locations where particle arrivals for each of the four sources were counted. Note that in all of the following figures documenting particle travel through the model grid (Figure 36 through Figure 42), particle counts have no physical meaning – they simply represent timing of water parcels originating at one of the three Sacramento River sources. Figure 36 documents that water parcels originating in the Mokelumne River do not reach Georgiana Slough or the North Fork of the Mokelumne River. Figure 37 documents Sacramento River water parcels from the three sources arriving at location SREM on the Sacramento River above the DCC. Figure 38 documents these parcels arriving at the upstream and downstream locations on Georgiana Slough; Figure 39 and Figure 40 documents these parcels arriving at four locations on the North Fork Mokelumne River; and, Figure 41and Figure 42 documents these parcels arriving at four locations on the South Fork Mokelumne River.

Table 1 provides documentation of the arrival time of particles released into the Sacramento River near the Regional San effluent outflow location for particles representing parcels without effluent and parcels when effluent flow restarts.

Table 1 Arrival Time for Two Particle Release Locations near Regional San Effluent Outflow Location

Release Location **Release Time**	**No Reg San** **10 Sep. 00:00**	**Reg San Late** **9/12/2020 1:00**
Arrival Location	***Arrival Time***	***Arrival Time***
SREM	10 Sep 19, 13:30	12 Sep 19, 14:15
GS1	10 Sep 19, 19:45	12 Sep 19, 19:30
GS4	11 Sep 19, 06:45	13 Sep 19, 06:30
NFM1	10 Sep 19, 18:00	12 Sep 19, 18:00
NFM2	10 Sep 19, 20:30	12 Sep 19, 21:30
NFM3	10 Sep 19, 23:00	12 Sep 19, 24:00
NFM4	11 Sep 19, 05:45	13 Sep 19, 06:30
SFM1	10 Sep 19, 19:15	12 Sep 19, 20:30
SFM2	10 Sep 19, 22:45	13 Sep 19, 00:15
SFM3	11 Sep 19, 07:30	13 Sep 19, 09:00
SFM4	11 Sep 19, 20:15	13 Sep 19, 13:30

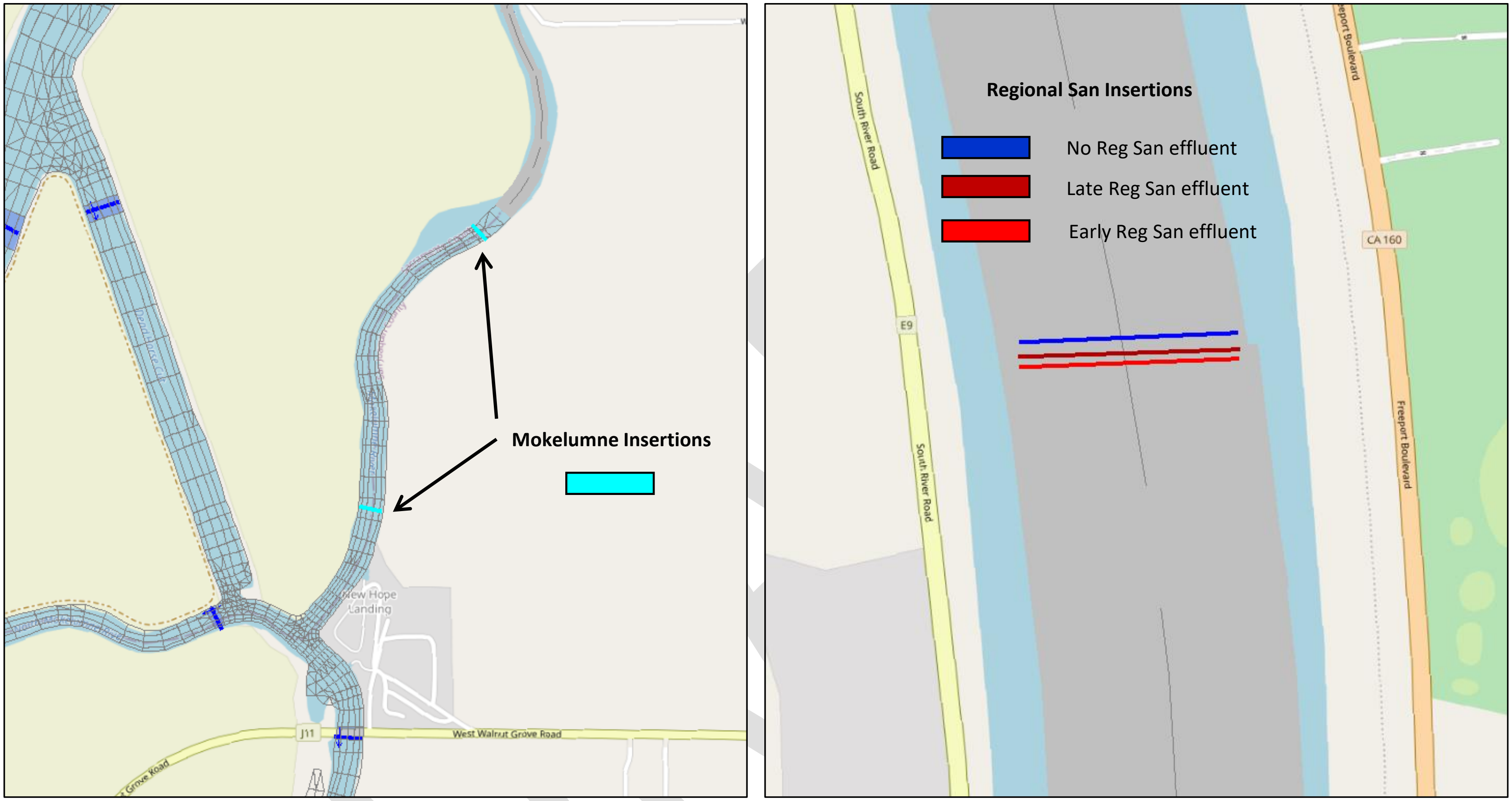


Figure 35 Location of particle insertion lines – cyan blue in left hand figure are the locations of Mokelumne particle insertion, and the right hand figure shows the locations of Regional San particle insertions.

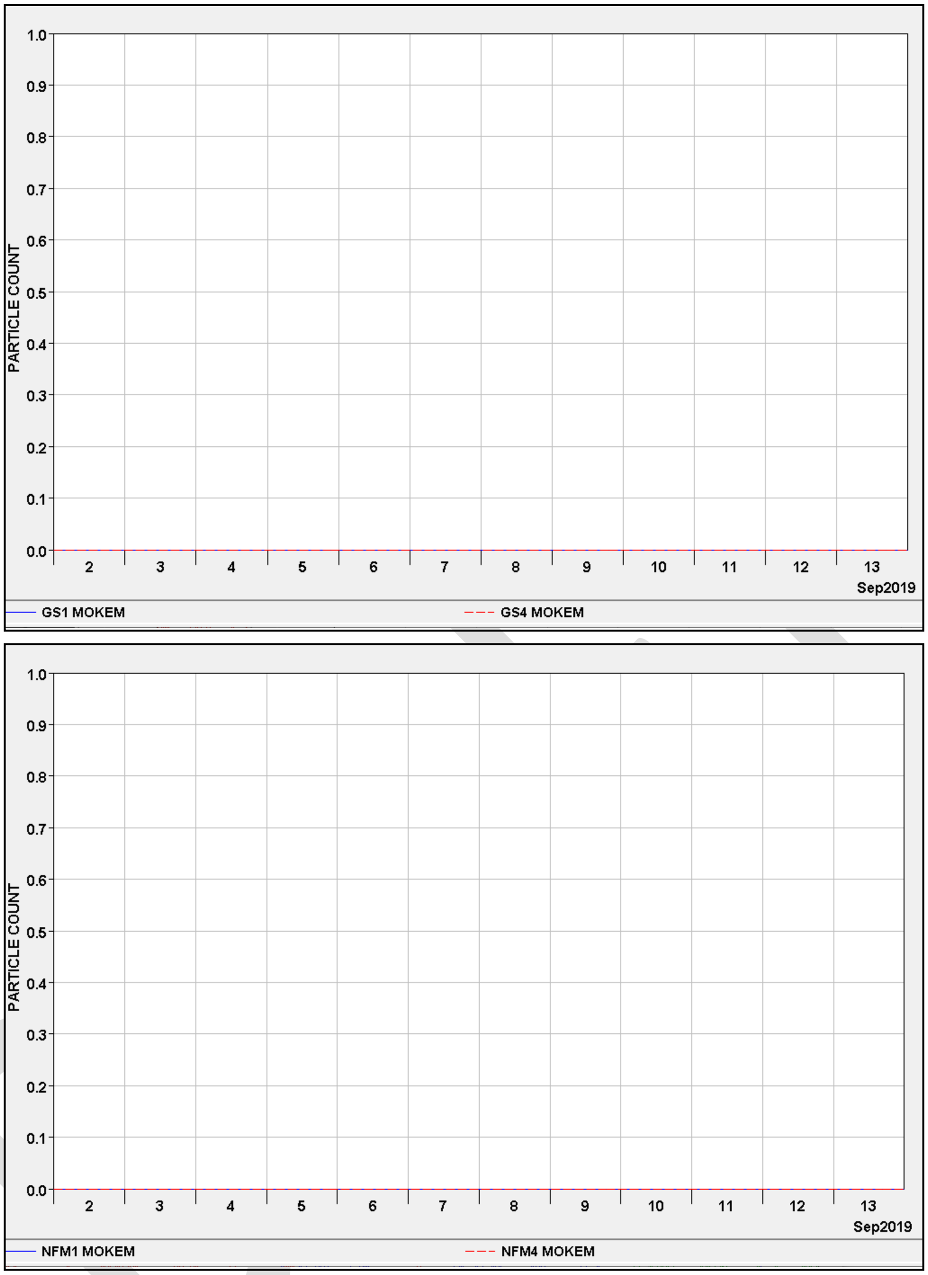


Figure 36 Particles originating at the MOKEM source do not reach either Georgiana Slough (top figure) of the North Forth of the Mokelumne River (lower figure).

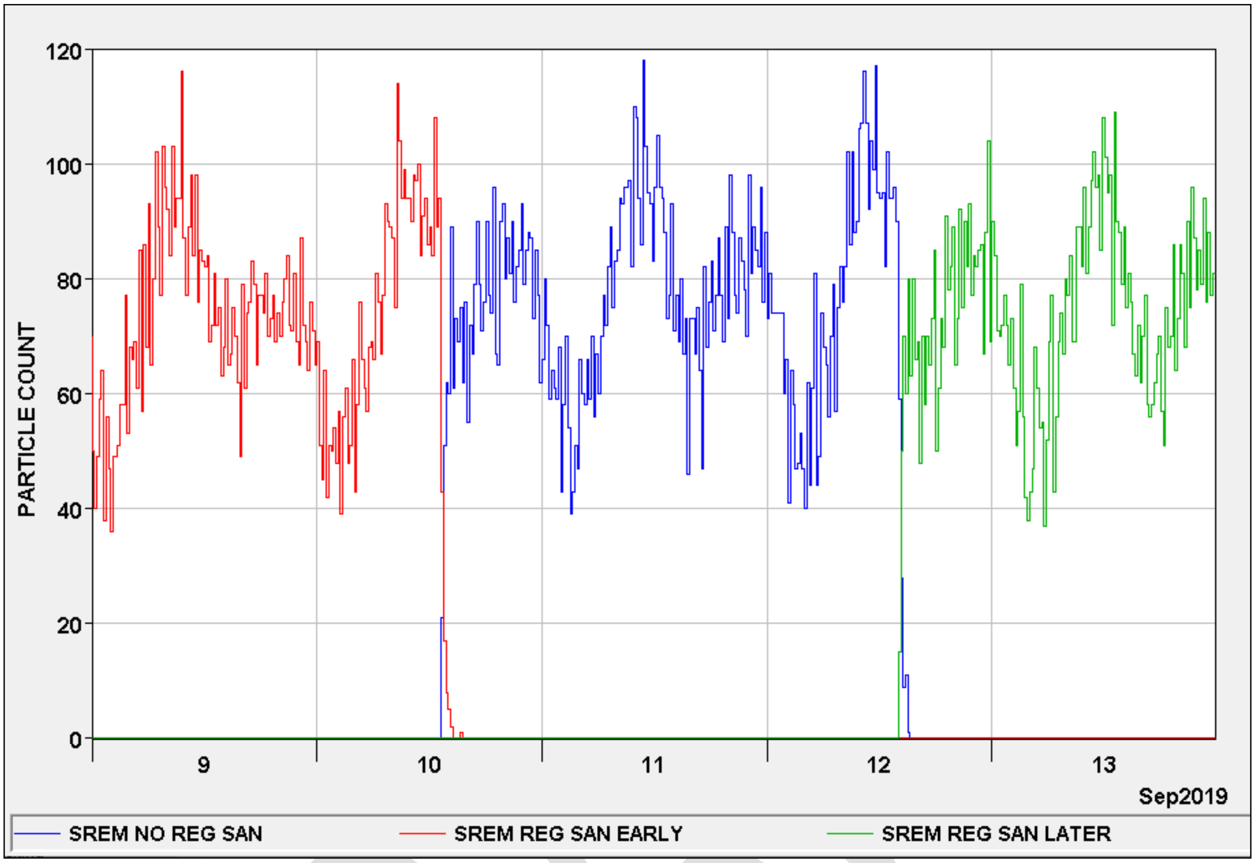


Figure 37 Particle arrival timing for particles representing Sacramento River water parcels arriving at the SREM location. Particle counts have no physical meaning as particle insertion values were designed for ease of visual interpretation.

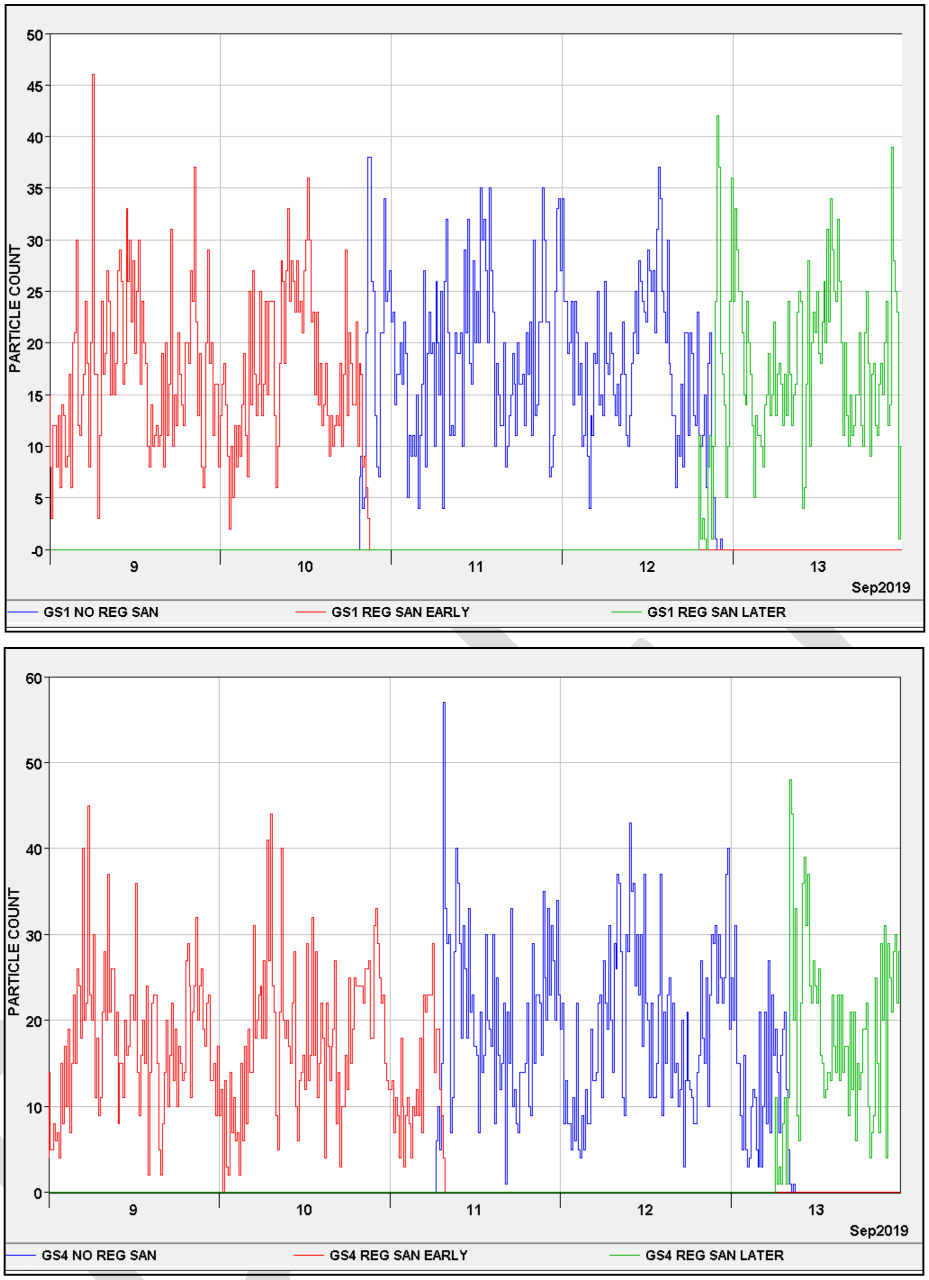


Figure 38 Particle arrival timing for particles representing Sacramento River water parcels arriving at the GS1 (upper figure) and GS4 (lower figure) locations. Particle counts have no physical meaning as particle insertion values were designed for ease of visual interpretation.

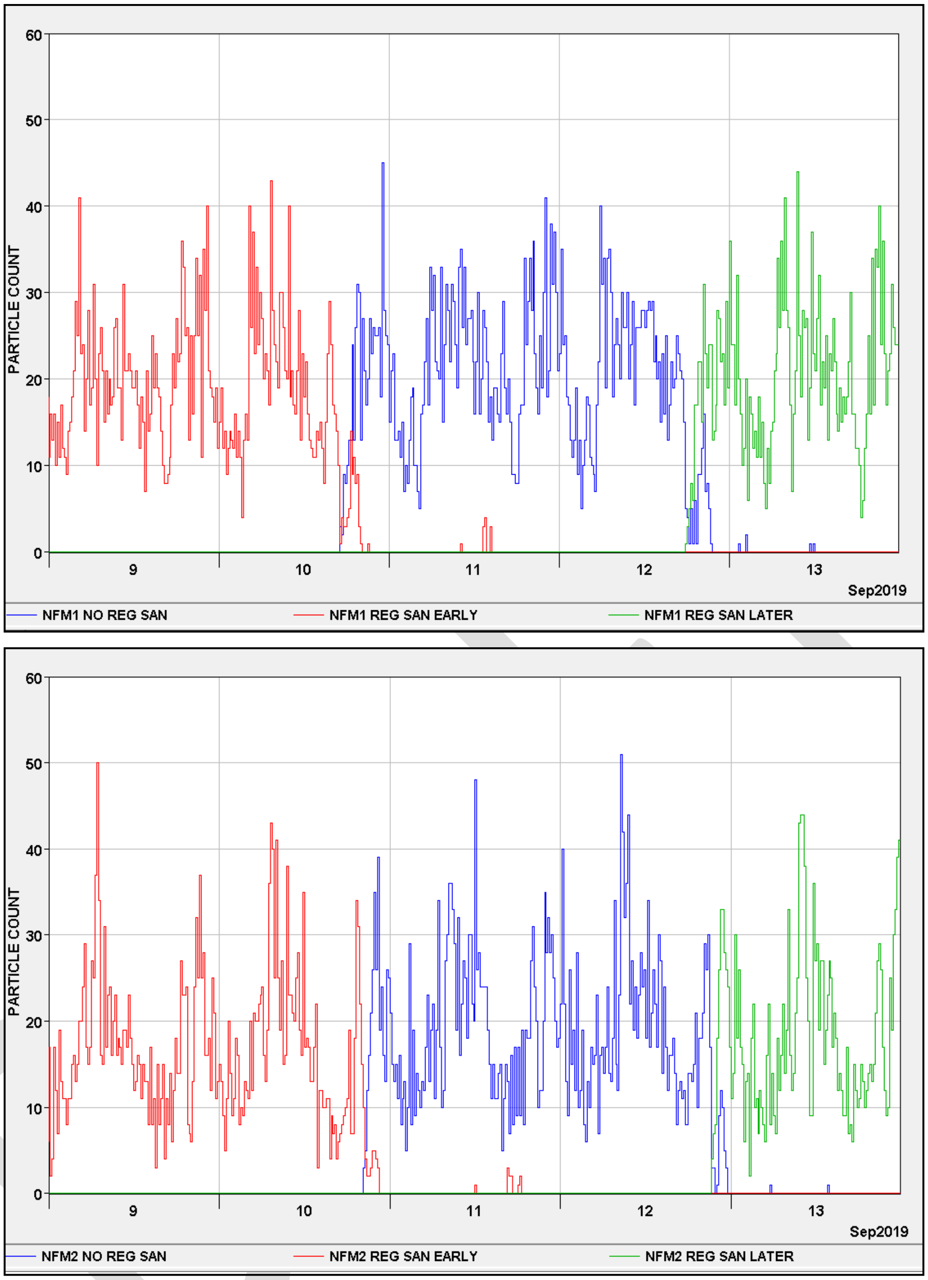


Figure 39 Particle arrival timing for particles representing Sacramento River water parcels arriving at the NFM1 (upper figure) and NFM2 (lower figure) locations. Particle counts have no physical meaning as particle insertion values were designed for ease of visual interpretation.

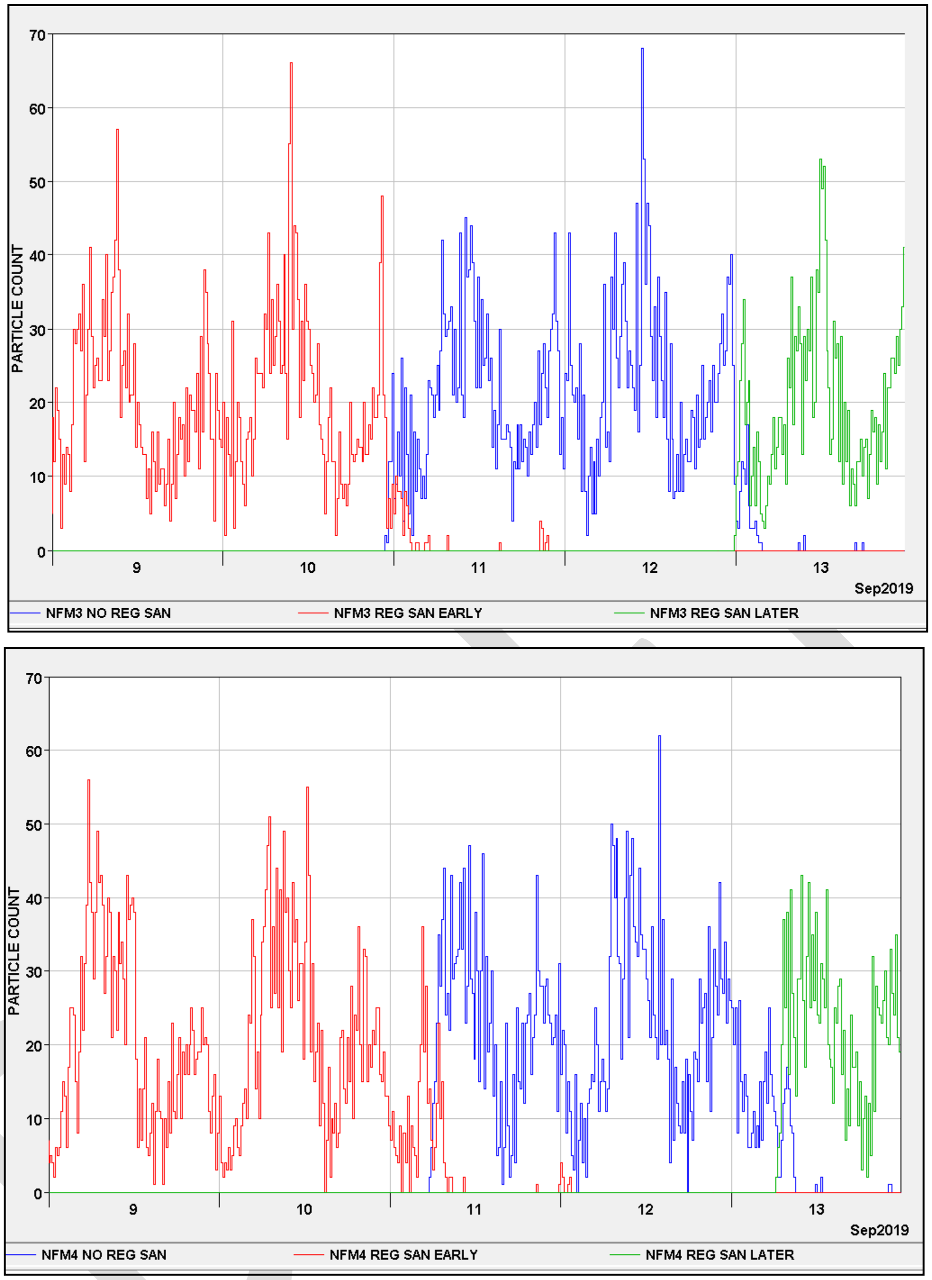


Figure 40 Particle arrival timing for particles representing Sacramento River water parcels arriving at the NFM3 (upper figure) and NFM4 (lower figure) locations. Particle counts have no physical meaning as particle insertion values were designed for ease of visual interpretation.

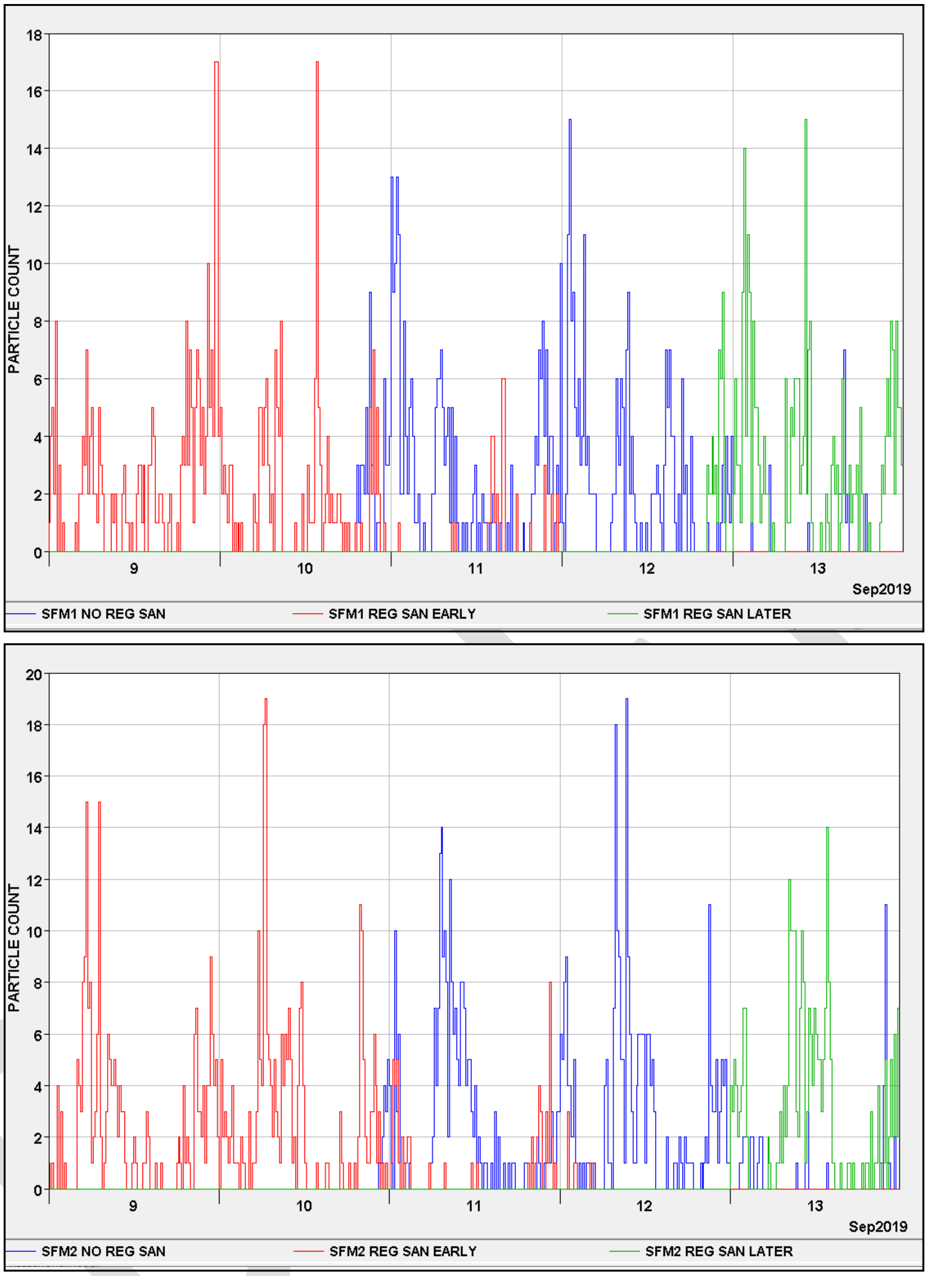
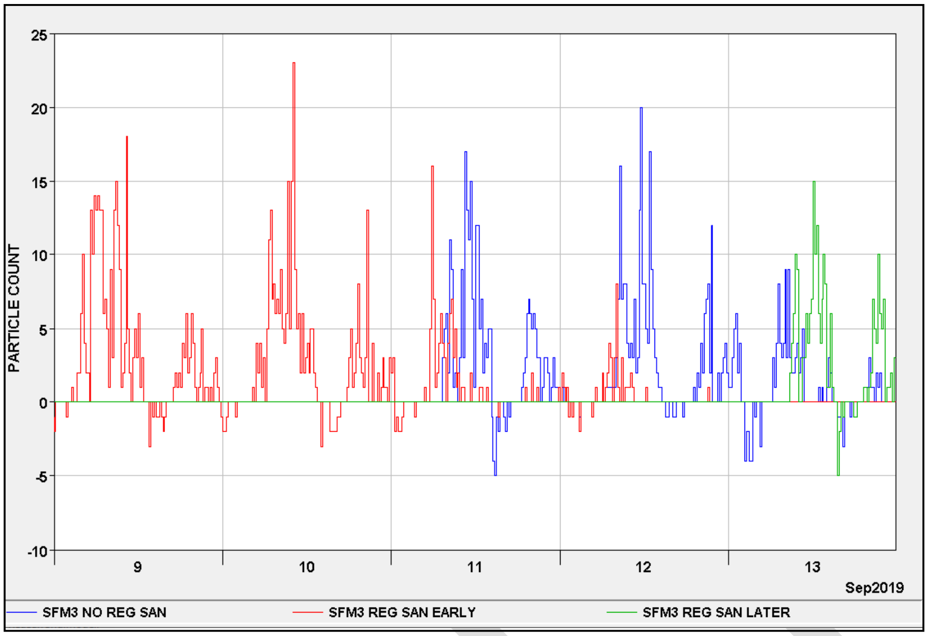


Figure 41 Particle arrival timing for particles representing Sacramento River water parcels arriving at the SFM1 (upper figure) and SFM2 (lower figure) locations. Particle counts have no physical meaning as particle insertion values were designed for ease of visual interpretation.



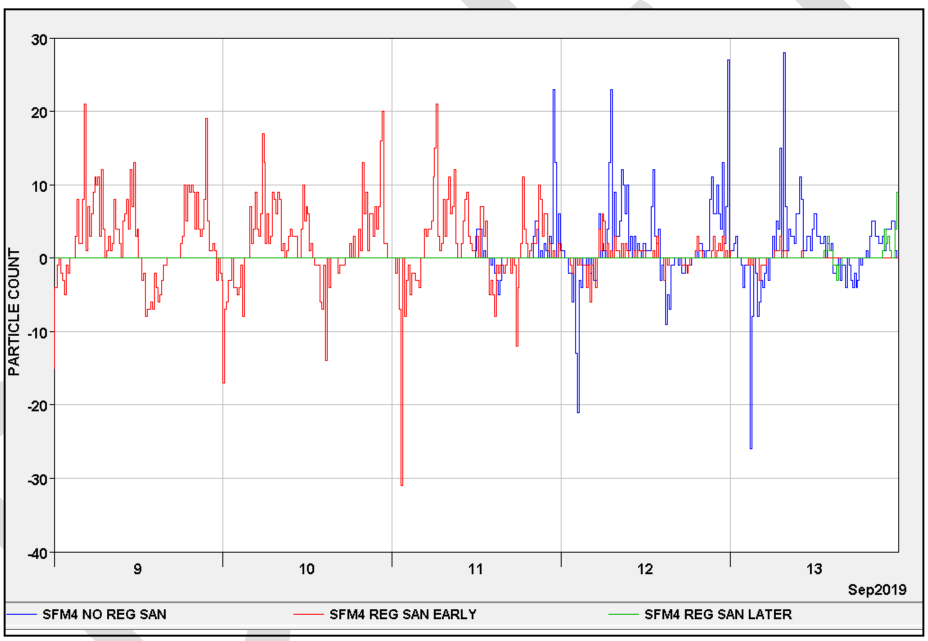


Figure 42 Particle arrival timing for particles representing Sacramento River water parcels arriving at the SFM3 (upper figure) and SFM4 (lower figure) locations. Particle counts have no physical meaning as particle insertion values were designed for ease of visual interpretation.

Summary of Results

Difficulties encountered during the calibration of the RMA11 EC model dispersion parameters highlighted the unfortunate loss of the North Fork and South Fork Mokelumne River flow, stage and EC monitoring stations east of the Delta Cross Channel during the 2017 winter season. Without the 15-minute data for flow, stage and EC data from these stations, the July-September 2019 project simulations are at a loss to sensibly estimate the accuracy of the tidal timing, flow magnitude or EC along the two forks of the Mokelumne River. As noted in Section 2, the dynamics of the South Fork Mokelumne (SMF) inter-tidal flow are characterized by intricate peaks and troughs during the 2016 calibration period. During this initial calibration period, flow station plots show the model phase is in advance of the observed flow phase, with the modeled phase several minutes advanced with respect to the field measured flow.

Because of this missing data during the 2019 study period, our expectation that the timing difference between model and project EC data measurements would be offset, in our case, by an unknown quantity on the order of minutes to hours was in fact observed. The timing difference of modeled EC in RMA11 in comparison with USGS high frequency field data was generally observed to be at most several hours, and on the order of an hour or less when comparing model output to the Regional San transect EC measurements.

At the split of the Mokelumne into north and south forks, the USGS data measurements were never resolved in the model. However, assuming the two dimensional grid only partially captured the physical detail, the model output was sensible if the inadequate resolution represented partial mixing of the sources. At the downstream end of the South Fork of the Mokelumne, it appeared that the range of tidal flow from Little Potato Slough influenced the modeled EC to a greater extent than expressed by the USGS data measurements.

Apart from these model characteristics, the model clearly captured that the North Fork of the Mokelumne River was sourced from a tidally influenced mixture of the Sacramento River, Regional San effluent and the Mokelumne River under the flow conditions during the project period September 10 -12, 2019. Georgiana Slough didn’t experience any inflow from the Mokelumne source as expected. The South Fork of the Mokelumne was a complex mixture of the three sources with a long travel time that muted the tidal influence as it traveled. The effect of the three side sloughs was also complex, and the model output along with the USGS data suggests these sloughs are potential sources of constituents including EC.